DOCUMENT RESUME

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DESCRIPTORS	Behavioral Objectives; Course Descriptions; Curriculum Guides; Drafters; *Drafting; *Engineering Drawing; Engineering Technicians; Geometric Concepts; High Schools; Learning Activities; Manuscript Writing (Handlettering); *Orthographic Projection; Postsecondary Education; Technical Education; *Technical Illustration
IDENTIFIERS	Military Curriculum Project

ABSTRACT

This outline of instruction, instructor guide, and student job sheets for a secondary-postsecondary-level course in Drafting I are one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. Purpose stated for the sixty-three-hour course is to teach the student to use drafting tools and perform the techniques and procedures related to basic drafting. The plan of instruction suggests number of hours of classroom and practical experience time for nine lessons: Lettering, Technical Sketching, Geometric Construction, Orthographics, Sections and Dimensions, Auxiliary Projection, Isometric and Oblique Drawings, Reproduction Processes, and Tracing. The outline of instruction gives objectives; lists of texts, references, tools, equipment and materials, training aids and devices, and training aids equipment; and a master schedule. Instructor guides provide lesson plans with an outline of instructional content, instructor and student activities, criterion objectives, tests, and review questions and answers. Eight job sheets are provided. A required chapter from a recommended text is included; other military and commercially published books, slides, transparencies, and films are suggested. (YLB)

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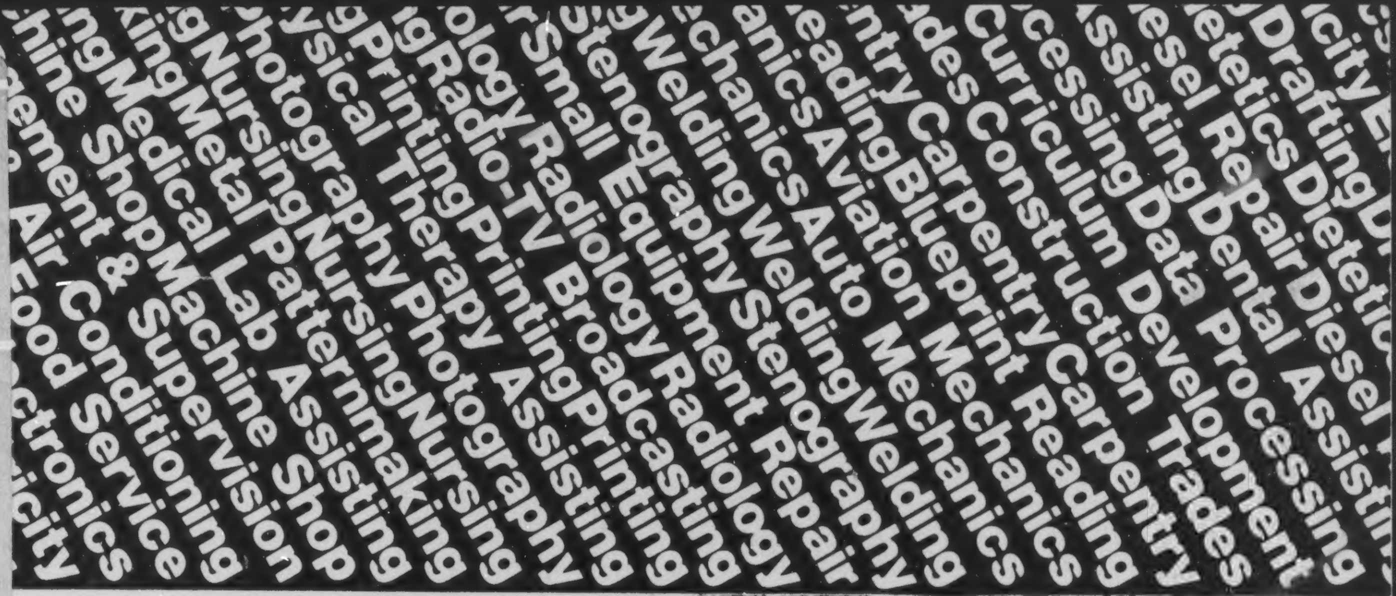
DraftingDraftingD
DieteticsDietetic
Diesel RepairDiesel R
Dental AssistingDental Assisting
Data ProcessingData Processing
Curriculum Development
Construction Trades
CarpentryCarpentry
Blueprint Reading
Aviation Mechanics
Auto Mechanics
WeldingWelding
StenographyStenography
Small Equipment Repair
RadiologyRadiology
Radio-TV Broadcasting
PrintingPrinting
Physical Therapy Assisting
PhotographyPhotography
NursingNursing
Metal Patternmaking
Medical Lab Assisting
Machine ShopMachine Shop
Management & Supervision
Air Conditioning
Food Service
Electronics
Electricity

Military Curricula for Vocational & Technical Education

DRAFTING I

6-3

U.S. DEPARTMENT OF HEALTH
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

CE 024 426

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

This military technical training course has been selected and adapted by The Center for Vocational Education for "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education," a project sponsored by the Bureau of Occupational and Adult Education, U.S. Department of Health, Education, and Welfare.

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
[illegible]
[illegible] Cable: CTVOCEDOSU/Columbus, Ohio

Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

ENGINEERING AID SCHOOL, DRAFTING I

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- Sections and Dimensions Page 112
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Engineering Aid 3 & 2, Navpers 10634-B

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ENGINEERING AID SCHOOL, DRAFTING I

Developed by:
United States Navy

Development and Review Dates:
June 1975

Occupational Area:
Drafting

Target Audiences:
Grades 11-adult

Print Pages:
289

Cost:
$6.00

Availability:
Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:	Type of Materials: Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Instructional Design: Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Type of Instruction: Group Instruction:	Individualized:
Unit 2 – Drafting 410.1												
1.2.1 Lettering	●			●		★	●	●	●	★	●	
1.2.2 Basic Technical Sketching	●			●	●	★	●	●	●	★	●	
1.2.3 Geometric Construction	●			●	●	★	●	●	●	★	●	
1.2.4 Orthographic Projection	●			●	●	★	●	●	●	★	●	
1.2.5 Sections and Dimensions	●			●	★	★	●	●	●	★	●	
1.2.6 Auxiliary Projection	●			●	●	★	●	●	●	★	●	
1.2.7 Isometric and Oblique Drawing	●			●	●	★	●	●	●	★	●	
1.2.8 Reproduction Processes	●			●	●	★	●	●	●	★	●	
1.2.9 Tracing	●						●	●	●	★	●	

★ Materials are recommended but not provided.

Expires July 1, 1978

THE CENTER FOR VOCATIONAL EDUCATION

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Course Description:

Students completing this short course will be able to use drafting tools and perform the techniques and procedures related to basic drafting. The course contains two units, but the first unit on course orientation and safety was deleted due to references to military procedures and organization. Unit 2—Drafting 410.1 contains the following nine lessons covering 63 hours of instruction:

1.2.1 Lettering (2 hours classroom, 2 hours practical)
1.2.2 Basic Technical Sketching (1 hour classroom, 5 hours practical)
1.2.3 Geometric Construction (3 hours classroom, 5 hours practical)
1.2.4 Orthographic Projection (2 hours classroom, 5 hours practical)
1.2.5 Sections and Dimensions (3 hours classroom, 6 hours practical)
1.2.6 Auxiliary Projection (2 hours classroom, 7 hours practical)
1.2.7 Isometric and Oblique Drawing (3 hours classroom, 6 hours practical)
1.2.8 Reproduction Processes (1 hour classroom, 1 hour practical)
1.2.9 Tracing (1 hour classroom, 8 hours practical)

This course contains both teacher and student materials. Printed instructor materials include an introduction to the course; an outline of instruction; outline of training objectives; lists of texts, references, tools, equipment and materials, training aids and devices, and training aids equipment; a master schedule; and instructor guides. The instructor guides contain the lesson plans with an outline of instructional content, instructor activities, student activities, criterion objectives, tests, and review questions and answers. Student materials consist of eight job sheets.

The text used for this course is a Navy Training Manual, *Engineering Aid 3 & 2, NAVPERS 10634-B*. The appropriate chapters are provided with this course. A commercially produced text is also recommended but not provided. Five military and 12 commercially published books are also recommended as references. Ten slides, 18 transparencies and the following 7 films are recommended for use with this course:

SN-34A	T-Square and Triangle, McGraw-Hill
SN-35Aq	Geometric Construction, McGraw-Hill
MC-6792-A	Engineering Drawing, Auxiliary Views
MC-6794-A	Engineering Drawing, Sections and Conventions
MC-6796-A	Engineering Drawing, Selections of Dimensions
MC-6797-A	Engineering Drawing, Orthographic Projection
MC-6797-C	Pictorial Sketching

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SEABEES

SPECIAL CONSTRUCTION BATTALION TRAINING

ENGINEERING AID SCHOOL
420.1 DRAFTING I

JUNE 1975

DEPARTMENT OF THE NAVY
NAVAL CONSTRUCTION TRAINING CENTER

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TITLE PAGE

TITLE: DRAFTING I

COURSE: Special Construction Battalion Training (SCBT) Course 420.1

COURSE LENGTH: 64 Contact Hours

TAUGHT AT: Naval Construction Training Center, Port Hueneme, CA 93043
Naval Construction Training Center, Gulfport, MI 39501

CLASS CAPACITY: Normal: 10
Maximum: 12
Minimum: 6

INSTRUCTOR REQUIREMENT PER CLASS: Class: 12:1
Pract: 12:1

COURSE CURRICULUM MODEL MANAGER: Naval Construction Training Center, Port Hueneme, CA 93043

QUOTA MANAGEMENT AUTHORITY: School at which taught.

QUOTA CONTROL: School at which taught.

APPROVAL/IMPLEMENTATION DATE: CNTT ltr N335:ath 1500 Ser 33/515 dated 25 June 1975

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HOW TO USE INSTRUCTOR GUIDES

Instructor Guides are provided for each topic and include supporting instructional materials and aids identified by the topic number and preceded by a letter code designation. The letter code key is as follows:

AS - Assignment Sheet
JS - Job Sheet
IS - Information Sheet
CN - Class Notes
OS - Operation Sheet
T - Test
FT - Final Test
TR - Transparency
DS - Diagram Sheet
PS - Problem Sheet
PT - Pretest
PE - Performance Evaluation
WS - Work Sheet
G - General (give a definition of item)

A complete listing of all supporting materials and aids is documented with full descriptive titles in Annex.

The instructor guides are intended to be used as master lesson plans subject to personalization by the individual instructor. In all cases, it is expected that the instructor will study the references in preparation for annotating the guide. It is also expected that each instructor will develop an appropriate introduction for each topic that will (1) create interest, (2) show the value of the topic to the student, (3) relate the topic to previous and future topics in the course, and (4) communicate the learning objectives to the student. Well prepared introduction will then provide the important motivational conditioning to establish readiness and effect for learning appropriate to each topic.

The first page of each instructor guide contains the following functional information:

1. Topic of lesson.
2. Time in periods.
3. References.
4. Instructional Materials.
5. Instruction Aids.
6. Objectives (Terminal and Enabling).
7. Topic criterion test (as applicable).
8. Homework assignment (when applicable).
9. Tools and materials.

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The pages following page 1 of each instructor guide provide in a three-column format the teaching/learning procedures for conducting the lesson. The left hand column includes the outline of instructional content required by the objectives; the center column includes recommended instructor activities or methodology; the center column contains recommended student learning activities.

While the methodology and student learning activities documented in each instructor guide have been tested and proven to be effective for the lead school, those schools implementing this curriculum are encouraged to exercise creativity in designing learning exercises and conceiving methods and techniques to meet course objectives.

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COURSE DATA PAGE

COURSE MISSION: To train selected Engineering Aids in the knowledge and technical skills defined by the personnel ratings and capability program for Engineering Aid Skill 420.1.

PERSONNEL AND RATINGS ELIGIBLE: CA, CN, EACA through EA3

OBLIGATED SERVICE: N/A

NOBC/NEC: N/A

PHYSICAL REQUIREMENTS: N/A

SECURITY CLEARANCE REQUIRED: None

PREREQUISITE TRAINING AND/OR BASIC BATTERY TEST SCORE REQUIRED: Applied Engineering Mathematics Skill Level 1 (400.1) or combined ARI/GCT score of 105.

RELATED TRAINING: None

FOLLOW-UP TRAINING: Drafting II, Course 420.2A, B, C, D, E

PERFORMANCE OF THE TASKS AND TESTING: Throughout the course the student will be evaluated on a pass/fail basis. The student performance on drawing assignments and exercises will meet a standard set by the instructor that will be acceptable in the field. The student will obtain at least 80 percent on all written topic tests.

OUTLINE OF INSTRUCTION

TOPIC	UNIT 1 INTRODUCTION	CLASS	PRACT	TOTAL	PAGE
1.1.1	Registration and Orientation	1	0	1	3
		1	0	1	
	UNIT 2 DRAFTING 410.1				
1.2.1	Lettering	2	2	4	3
1.2.2	Basic Technical Sketching	1	5	6	3
1.2.3	Geometric Construction	3	5	8	4
1.2.4	Orthographic Projection	2	5	7	4
1.2.5	Sections and Dimenstions	3	6	9	4
1.2.6	Auxiliary Projection	2	7	9	5
1.2.7	Isometric and Oblique Drawing	3	6	9	5
1.2.8	Reproduction Processes	1	1	2	5
1.2.9	Tracing	1	8	9	6
		18	45	63	

*	Total Periods Classroom	19
*	Total Periods Practical	45
	Total Hours for Course	64
	Total Weeks for Course	2 Weeks

* All periods represent 60 minutes of actual instruction.

OUTLINE OF TRAINING OBJECTIVES

Unit 1.1 INTRODUCTION Contact Hours: 1

Terminal Objective: Upon completion of this unit the student will have registered for the course, received text books, complied with NAVCONSTRACEN and CBC regulations governing the reporting and fighting of fires which pertain to him as a SCBT student.

Topic 1.1.1 REGISTRATION AND ORIENTATION Contact Hours: 1

Enabling Objectives: Upon completion of this topic the student will be able to answer orally specific questions pertaining to the mission, regulations and organization of the Command, and the method of reporting and fighting fires as established by NAVCONSTRACEN and CBC regulations. This topic is not meant to be restricting.

Unit 1.2 DRAFTING Contact Hours: 63

Terminal Objective: Upon completion of this unit the student will be able to use the tools of a draftsman and perform the techniques and procedure-related to basic drafting. All problem solutions submitted by the student as his finished product will meet the minimum requirements of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1

Topic 1.2.1 LETTERING Contact Hours: 4

Enabling Objective: Upon completion of this topic the student will be able to complete three free-hand lettering exercises using single-stroke Gothic-style lettering of proper size, spacing and opaqueness. Individual instructor guidance, commercial lettering books, and examples of notations made on sample drawings may be utilized in the performance of the requirements of this topic. The lettering exercises submitted by the student as his finished product will meet the acceptable standards of SCBT 420.1 EA EG 1.2.0.1 for uniformity, size, spacing of letters, words and sentences, and opaqueness.

Topic 1.2.2 BASIC TECHNICAL SKETCHING Contact Hours: 6

Enabling Objectives: Upon completion of this topic the student will be able to make free-hand technical sketches from objects, notes and verbal descriptions that can be used to develop descriptive construction and shop drawings. Student textbooks, commercial technical sketching publications and the guidance of the instructor may be utilized in the performance of the requirements of this topic. All sketches submitted by the student as his finished product will be of proper proportions to represent the object sketched and contain opaque visible lines as well as proper shading or rendering sufficient enough to make a legible Diazo reproduction.

Topic 1.2.3 GEOMETRIC CONSTRUCTION Contact Hours: 8

Enabling Objectives: Upon completion of this topic the student will be able to construct two plane geometric figures that include circular and curved surfaces, using standard drafting instruments. Textbooks, other drafting publications and instructor guidance may be utilized in the performance of the requirements of this topic. Templates, however, may not be used. All figures submitted by the student as his finished assignment will meet the acceptable standards of SCBT 420.1 EA EG 1.2.0.1 for visible lines, tangents, format, accuracy and solution and of an opaque-quality sufficient enough to make a legible Diazo reproduction.

Topic 1.2.4 ORTHOGRAPHIC PROJECTION Contact Hours: 7

Enabling Objectives: Upon completion of this topic the student will be able to construct two, three-view orthographic drawings of mechanical and construction objects following the fundamentals of orthographic projection while using standard drafting instruments. Textbooks, other drafting publications or references as well as instructor guidance are encouraged in the completion of the requirements. Tracing of a completed orthographic drawing, other than one executed by the student, and the use of templates are not acceptable drawing procedures. All drawings submitted by the student as his finished assignment will meet the acceptable standards of SCBT 420.1 EA EG 1.2.0.1 for visible lines, line conventions, tangents, format, accuracy and solution. In addition, all drawings must be of opaque-quality sufficient enough to make a legible Diazo reproduction.

Topic 1.2.5 SECTIONS AND DIMENSIONS Contact Hours: 9

Enabling Objectives: Upon completion of this topic the student will be able to construct three sectional views of mechanical and construction objects with dimensions and notes as specified for mechanical and construction drawings while using standard drafting instruments. Tracing of a completed drawing other than one executed by the student and the use of templates are not acceptable drawing procedures. The drawing submitted by the student as his finished assignment will meet the acceptable standards of SCBT 420.1 EA EC 1.2.0.1 for all 10 parts of a drawing and of an opaque-quality sufficient enough to make a legible Diazo reproduction.

Topic 1.2.6 AUXILIARY PROJECTION Contact Hours: 9

Enabling Objectives: Upon completion of this topic the student will be able to construct a two-view orthographic drawing of a structure with an accompanying auxiliary view following the fundamentals of orthographic and auxiliary projection while using standard drafting instruments. The figures of the drawing are to be annotated with dimensions and notes as specified for construction drawings. Individual instructor guidance, textbooks and other drafting publications may be utilized. Tracing of completed drawing other than that executed by the student and the use of templates are not acceptable drawing procedures. The drawing submitted by the student as his finished assignment will meet the acceptable standards of SCBT 420.1 EA EG 1.2.0.1 for visible lines, notes, line conventions, tangents, format, lettering, numerals and fractions, accuracy and solution and of an opaque-quality sufficient enough to make a legible Diazo reproduction.

Topic 1.2.7 ISOMETRIC AND OBLIQUE DRAWING Contact Hours: 9

Enabling Objectives: Upon completion of this topic the student will be able to construct one isometric drawing, one oblique-cabinet drawing, and one oblique cavalier drawing of a mechanical and two construction objects following the fundamentals of isometric and oblique projection while using standard drafting instruments. The drawings will be construction drawings. Examples of various isometric and oblique drawings found in reference material and textbooks and the guidance of the instructor are encouraged in the performance of the requirements of this topic. Tracing of a completed drawing other than that executed by the student and the use of templates are not acceptable drawing procedures. The drawings submitted by the student as his finished assignment will meet the standards of SCBT 420.1 EA EG 1.2.0.1 for visible lines, notes, line conventions, tangents, format, lettering, numerals and fractions, accuracy, and solution and of an opaque-quality sufficient enough to make a legible Diazo reproduction.

Topic 1.2.8 REPRODUCTION PROCESS Contact Hours: 2

Enabling Objectives: Upon completion of this topic the student will be able to fold and file prints as well as operate a Diazo reproduction machine to reproduce copies of his drawings completed and noted in the requirements of the previous topics of this unit. A minimum of one completed drawing or exercise from each topic noted is to be reproduced (except Topic 1.2.1 "Lettering"). He will be able to prepare the Diazo reproduction machine for operation, operate the machine at the proper speed with the proper amount of developing agent to produce copies of his drawings to give a line resolution equal to the line value or opaqueness of the original drawings, and be able to secure the machine without damage to the exposure and developing sections of the reproduction

Topic 1.2.8 Reproduction Process (cont'd)

machine. Students will fold a "F" size print to 8 1/2" X 11" following the procedures set forth in Engineering Aid 3 & 2, NAVPERS 10634-B with 100 percent accuracy.

Topic 1.2.9 TRACING Contact Hours: 9

Enabling Objectives: Upon completion of this topic the student will be able to trace drawings following the procedures set forth in the instructors guide. Individual instructor guidance and student tests can be utilized in the performance of the requirements of this topic. The tracing submitted by the student as his finished product will be 100% accurate for all details when compared with the original drawing and will meet the acceptable standards of 3CBT 420.1 EA EG 1.2.0.1 for all 10 parts of a good drawing.

ANNEX I

TEXTS

1. Engineering Aid 3 & 2, NAVPERS 10634-B Rate Training Manual, Washington D.C., Training Publications Division of the Naval Personnel Program Support Activity.
2. Engineering-Technical Drafting and Graphics, J.W. Gianchino and Henry J. Beukema, Pub: Chicago: American Technical Society, 1966 2nd Edition.

ANNEX II

REFERENCES

1. MIL-STD-100A - General Drawing Practices
2. MIL-STD-14A - Architectural Symbols
3. MIL-STD-15-3 - Military Standard Electrical Symbols
4. MIL-STD-17B-1 - Military Standard Mechanical Symbols
5. MIL-STD-18A - Structural Symbols
6. Standard Welding Symbols, AWS-A2, 0-68
7. Architectural Graphic Standards, 5th Edition
8. Engineering Aid 3&2, NAVPERS 10634-B
9. TM5-233 - Construction Surveying
10. TM5-530 - Materials Testing
11. Architectural Drawing and Light Construction by Muller
12. Blueprint Reading and Sketching, NAVPERS 10077C
13. Engineering Drawing by French & Vierck, 10th Edition
14. Architectural Drafting by Hornung
15. TM5-230 - General Drafting
16. MIL-STD-8C - Dimensioning
17. Technical Drafting, Geske, Mitchell & Spencer

ANNEX III

TOOLS, EQUIPMENT AND MATERIAL

EQUIPMENT

1. Diazit Space Saver Printer/Developer
2. Diazit Pump-It Ammonia Pump
3. Four NMCB Draftsman Kits including the following items:

FSN/MFG NO.		QTY	COST	EXT. COST
90G 5110-293-1585	Knife, Craftsman, Lt. Dty.	1 Set	.70	.70
90L 5210-086-4988	Tape, Meas. Flex Metric 3M	2 Ea.	1.55	3.10
9GD 6230-299-7771	Desk Lamp	3 Ea.	15.70	47.10
9GD 6675-042-9947	Reservoir Pen Set, Drafts.	2 Ea.	18.10	36.20
9GD 6675-184-5763	Planimeter	1 Ea.	71.00	71.00
9GD 6675-190-5852	Triangle 30/60D 12 Inch	3 Ea.	.44	1.32
9GD 6675-190-5857	Triangle 45D 6 Inch	3 Ea.	.14	.42
9GD 6675-190-5858	Triangle 30/60D 6 Inch	3 Ea.	.20	.60
9GD 6675-190-5864	Triangle 45D 12 Inch	3 Ea.	.69	2.07
9GD 6675-191-1502	T-Square, Dbl. Hd, 36 Inch	2 Ea.	5.49	10.98
9GD 6675-234-5099	Scale, Draft, Architect	1 Ea.	6.00	6.00
9GD 6675-238-3498	Scale, Engr. Tri.12	3 Ea.	3.19	9.57
9GD 6675-239-0614	Straightedge, Cres. Drafts. 42 Inch	1 Ea.	9.76	9.76
9GD 6675-240-2049	Dividers, Proportional	1 Ea.	14.50	14.50
9GD 6675-243-6432	Compass Beam Steel	1 Ea.	55.00	55.00
9GD 6675-291-9382	Line Guide, Lettering	3 Ea.	.54	1.62

ANNEX III (Cont.)

3. Four NMCB Draftsman Kits including the following items: (Cont.)

9GD 6675-514-3519	Triangle 45D 18 Inch	2 Ea.	2.05	4.10
9GD 6675-514-3537	Curve, Draft, Irreg., Fr. #13	2 Ea.	.30	.90
9GD 6675-514-3542	Triangle 30/60D 18 Inch	3 Ea.	1.10	3.30
9GD 6675-514-3544	Protractor, 360 Deg. 8 Inch	3 Ea.	1.30	3.90
9GD 6-75-514-3549	Scale, Arch. Tri. 12 Inch	3 Ea.	1.93	5.79
9GD 6675-550-7036	Drawing Board, 60X42	3 Ea.	62.00	186.00
9GD 6675-551-0786	Lettering Set	1 Ea.	37.40	37.40
9GD 6675-641-3529	Drafting Instrument Set Fld	2 Set	9.02	18.04
9GD 6675-641-5727	Scale, Draft. Metric, 2 Bvl 30 CM and 12 Inch, Grad. Lth	3 Ea.	3.25	9.75
9GD 6675-827-2073	Parallel Straightedge, 48	3 Ea.	15.20	45.60
9GD 6675-847-0222	French Cruve	3 Ea.	.73	2.19
9GD 6675-847-0224	Curve, Draft, Irreg. Fr. #34	3 Ea.	.86	2.58
9GD 6675-926-4330	Template, Set, Plst, Draft.	1 Set	20.40	20.40
90G 7490-770-7955	Eraser, Electric	3 Ea.	16.88	50.64
70L 7510-CC0-4288	Eraser, 7 In. Vinyl, for Electric Eraser 7490-770-7955	1 Dz.	1.15	1.15
90G 7510-161-5660	Penholder, Blk, Cork Grip	1 Dz.	.96	.96
90G 7510-189-7877	Pencil, F	1 Dz.	.35	.35
90G 7510-189-7878	Pencil, HB	1 Dz.	.35	.35
90G 7510-189-7880	Pencil, 2H	1 Dz	.35	.35
90G 7510-189-7881	Pencil, 3H	1 Dz.	.35	.35
90G 7510-198-5831	Tape, Pressure, Draft 1 In.	6 Rl.	.31	1.86
90G 7510-224-6744	Ink, Draw. Blk	1 Oz.	.13	.13

ANNEX III (Cont.)

3. Four NMCB Draftsman Kits including the following items: (Cont.)

90G 7510-224-7242	Shield, Eraser, Stl	1 Dz.	.61	.61
70L 7510-229-8732	Erasing Fluid, F/Sensitive, D Paper, 2 Solution Set	1 Oz.	1.05	1.05
90G 7510-233-0570	Ink, Drawing, Carmine	3 Oz.	.13	.39
90G 7510-237-4926	Pencil Pointer	3 Ea.	.10	.30
90G7510-237-7043	Ink, Drawing, Green	1 Oz.	.13	.13
90G 7510-264-4614	Pencil, H	1 Dz.	.35	.35
90G 7510-272-9820	Lead Pencil, Dwg. Blk. 3H	2 Pg.	.15	.30
70L 7510-281-2134	Lead Pencil, Dwg. Blk. HB	6 Bx.	.44	2.64
90L 7510-285-5863	Lead Pencil, Dwg. Blk. 3H	6 Pg.	.15	.90
90L 7510-285-5864	Lead Pencil, Dwg. Blk. 4H	24 Pg.	.15	3.60
90L 7510-285-5865	Lead Pencil, Dwg. Blk. F	24 Pg.	.15	3.60
90V 7510-285-5866	Lead Pencil, Dwg. Blk. H	2 Pg.	.15	.30
90G 7510-551-9825	Tape, Pressure Sens. Transp. 3/4 In. X 36 Yd for use in Dispenser 7520-240-2408	12 Rl.	.27	3.24
90G 7510-558-2422	Cleaner Pen 6 Ox.	3 Jr.	.30	.90
90G 7510-579-8551	Eraser, Lead	1 Dz.	.60	.60
90G 7510-634-3513	Refill, Eraser Elec.	1 Gr.	1.66	1.66
90G 7510-634-5035	Eraser, Pencil	1 Dz.	.49	.49
9GH 7510-960-9286	Pad, Drycleaning, Drafts.	12 Ea.	.55	6.60
90G 7520-162-6178	Sharpener, Pencil	1 Ea.	1.44	1.44
90G 7520-224-7593	Sharpener, Pencil, Draft.	1 Ea.	1.49	1.49
90G 7520-224-7621	Trimmer Paper	1 Ea.	29.36	29.36

ANNEX III (Cont.)

3. Four NMCB Draftsman Kits including the following items: (Cont.)

90G 7520-240-2408	Dispenser, Pres. Sens. Tape	1 Ea.	1.70	1.70
90L 7520-551-3654	Holder, Drawing, Lead	12 Ea.	.69	8.28
90L 7520-551-5227	Slide Rule, LogLog 101g	2 Ea.	9.48	18.96
90G 7520-827-2067	Pointer, Lead, F/Draft. Pncl	3 Ea.	9.58	28.74
90G 7530-286-6909	Paper, Graph	1 Rl.	2.63	2.63
90G 7530-286-7762	Paper, Tracing, 42"X50 Yd.	3 Rl.	8.86	26.58
90L 7530-290-5024	Paper, Graph, Profile, Tra. Wh w/orange lines, 22 In wide by 50 yd lg.	1 Rl.	3.50	3.50
90G 7530-616-7245	Paper, Plan Profile	1 Hd.	20.29	20.29
90G 7530-985-7266	Paper, Drawing, 36" X 10 Yd	1 Rl.	2.32	2.32
90G 7920-291-5812	Brush, Dust, Draftsman	3 Ea.	.68	2.04
		Total Value:		839.00

ANNEX IV

TRAINING AIDS AND DEVICES

A. Films:

1.	SN-34A	T-Square and Triangle, McGraw-Hill
2.	SN-35A	Geometric Construction, McGraw-Hill
3.	MC-6792-A	Engineering Drawing, Auxiliary Views, B&W, (23 min.)
4.	MC-6794A	Engineering Drawing, Sections and Conventions, B&W, (15 min.)
5.	MC-6796A	Engineering Drawing, Selection of Dimensions (18 min.)
6.	MC-6797A	Engineering Drawing, Orthographic Projection, B&W, (18 min.) Obsolete
7.	MC-6797C	Pictorial Sketching

B. Slides:

1.	091791	Orthographic Drawing, Part 1, Set 4, McGraw-Hill
2.	091792	Dimensioning, Part 1, Set 4, McGraw-Hill
3.	091793	Auxiliary Views and Related Construction, Set 4, McGraw-Hill
4.	091794	Orthographic Drawing, Part 2, Set 4, McGraw Hill
5.	091795	Dimensioning, Part 2, Set 4, McGraw-Hill
6.	091796	Sectional Views, Set 4, McGraw-Hill
7.	65618	Scales, Set 3, McGraw-Hill
8.	65619	Compass and Bow Instruments, Set 3, McGraw-Hill
9.	65620	Freehand Lettering, Set 3, McGraw-Hill
10.	65623	Isometric Drawing, Set 3, McGraw-Hill

ANNEX IV (Cont.)

C. Transparencies:

1.	11CS-1551-115T-1	Dissecting A Line
2.	11CS-1551-115T-2	Constructing Parallel Lines
3.	11CS-1551-115T-3	Constructing A Hexagon
4.	11CS-1551-115T-4	Constructing A Regular Hexagon - Across The Flats
5.	11CS-1551-115T-5	Constructing An Octagon In A Square
6.	11CS-1551-115T-6	Constructing An Irregular Polygon - Give One Side
7.	11CS-1551-115T-7	Constructing A Circle Tangent To A Given Line Passing Through A Given Point
8.	11CS-1551-115T-8	Constructing An Ellipse - 4 Center Method
9.	11CS-1551-115T-9	Constructing A Reverse Curve (Ogee)
10.	11CS-1551-115T-10	Bisecting A Line
11.	11CS-1551-115T-11	Bisecting An Angle
12.	11CS-3540-117T-1	Sketching All Necessary Views
13.	11CS-5600-101T-5	Photocomposing Machine
14.	11CS-5600-101T-6	Xerox 720
15.	11CS-5600-101T-7	Ozalid Streamliner
16.	11CS-5600-101T-8	Thermofax Machine
17.	11CS-10290.101T-1	T-Square, Jacobs and Drafting Machine
18.	11CS-10290.104T-1	Variations of Ruling Pens

D. Locally Prepared Material;

1. Evaluation Guide, SCBT 420.1 EA.EG.1.2.0.1

2. Job Sheets

   a. SCBT 420.1 EA.JS.1.2.1.1, "Lettering"

   b. SCBT 420.1 EA.JS.1.2.2.1, "Technical Sketching"

D. Locally Prepared Material: (Cont.)

c. SCBT 420.1 EA.JS.1.2.3.1, "Geometric Construction"

d. SCBT 420.1 EA.JS.1.2.4.1, "Orthographic Projection and Drawing"

e. SCBT 420.1 EA.JS.1.2.5.1, "Sectioning and Dimensioning"

f. SCBT 420.1 EA.JS.1.2.6.1, "Auxiliary Projection and Drawing"

g. SCBT 420.1 EA.JS.1.2.7.1, "Isometric and Oblique Projection and Drawing"

h. SCBT 420.1 EA.JS.1.2.8.1, "Reproduction Process"

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ANNEX V

TRAINING AIDS EQUIPMENT

1. Projectors:

    a. 16MM Motion Picture Projector

    b. 35MM Slide Projector

    c. Overhead Projector

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ANNEX VI

MASTER SCHEDULE

SCBT 420.1 ENGINEERING AID

FIRST WEEK

TOPIC NO.	TYPE	PERIOD	TITLE	RATIO
FIRST DAY				
1.1.1	C	1	Registration and Orientation	12/1
1.2.1	C	2	Lettering	12/1
		3		
	P	4		
		5		
1.2.2	C	6	Basic Technical Sketching	12/1
	P	7		
SECOND DAY				
1.2.2	P	8	Basic Technical Sketching	12/1
		9		
		10		
		11		
1.2.3	C	12	Geometric Construction	12/1
		13		
		14		
THIRD DAY				
1.2.3	P	15	Geometric Construction	12/1
		16		
		17		
		18		
		19		
1.2.4	C	20	Orthographic Projection	12/1
		21		
FOURTH DAY				
1.2.4	P	22	Orthographic Projection	12/1
		23		
		24		
		25		
		26		
1.2.5	C	27	Sections and Dimensions	12/1
		28		

ANNEX VI: (Cont'd)

FIRST WEEK (Cont'd)

TOPIC NO	TYPE	PERIOD	TYPE	RATIO
FIFTH DAY				
1.2.5	C	29	Sections and Dimensions	12/1
	P	30		
		31		
		32		
SECOND WEEK				
FIRST DAY				
1.2.5	P	1	Sections and Dimensions	12/1
		2		
		3		
1.2.6	C	4	Auxiliary Projection	12/1
		5		
	P	6		12/1
		7		
SECOND DAY				
1.2.6	P	8	Auxiliary Projection	12/1
		9		
		10		
		11		
		12		
1.2.7	C	13	Isometric and Oblique Drawing	12/1
		14		
THIRD DAY				
1.2.7	C	15	Isometric and Oblique Drawing	12/1
	P	16		
		17		
		18		
		19		
		20		
		21		

ANNEX VI (Cont'd)

TOPIC NO.	TYPE	PERIOD	TITLE	RATIO
FOURTH DAY				
1.2.8	C	22	Reproduction Process	12/1
	P	23		12/1
1.2.9	C	24	Tracing	12/1
	P	25		
		26		
		27		
		28		
FIFTH DAY				
1.2.9	P	29	Tracing	12/1
		30		
		31		
		32		

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
ENGINEERING AID SCBT 400-490

Classification: Unclassified

Topic: Introduction and Safety

Average Time: 1 Period (Class)

Instructional Materials:
A. Texts: None

B. References:

1. NAVCONSTRACEN Instruction 5400.4 (Current Series), Organization Manual of NAVCONSTRACEN

2. "Safety Practices for Shore Activities", NAVMAT P-5100, (Jan 73)

Terminal Objective: Upon completion of this unit the student will have registered for the course, received text books, complied with NAVCONSTRACEN and CBC regulations governing the reporting and fighting of fires which pertain to him as a SCBT student.

Enabling Objective: Upon completion of this topic the student will be able to answer orally specific questions pertaining to the mission, regulations and organization of the Command, and the method of reporting and fighting fires as established by NAVCONSTRACEN and CBC regulations.

Criterion Tests: The student will answer orally specific questions pertaining to the mission, regulations and organization of the Command, and the method of reporting and fighting fires as established by NAVCONSTRACEN and CBC Regulations.

Homework: None

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OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. INTRODUCTION TO THE LESSON	1. Introduce self and topic.	
A. Establish Contact.		
1. Name:		
2. Topic: Introduction and Safety		
B. Establish Readiness	2. Motivate student.	
1. Purpose		
2. Assignment		
C. Establish Effect	3. Bring out need and value of material being presented.	
1. Value		
a. Pass course.		
b. Perform better on the job.		
D. Overview:	4. State learning objectives:	
1. You will be able to answer orally specific questions related to the mission, regulations and organization of the Command, and the methods of reporting and fighting a fire as established by NAVCONSTRACEN and CBC regulations.	a. State information and materials necessary to guide student.	
2. Ask questions.		
3. Take notes		
4. Testable		

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OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

II. PRESENTATION:

A. Introduction

1. Mission

a. Special training course

b. Higher state of readiness,

c. Compliance with COMCBPAC Instruction.

2. Organization and Chain of Command

a. Commanding Officer

b. Executive Officer

c. Training Officer

d. School Department Officer

e. Division Director

f. Senior Instructor

h. Class Petty Officer

3. Regulations and policies

a. Break procedures

b. Uniform regulations

(1) Working uniform of the day.

(a) Must be neat and clean.

OUTLINE OF INSTRUCTION | INSTRUCTOR ACTIVITY | STUDENT ACTIVITY

c. Absenteeism

(1) Must be kept to a minimum.

(2) Medical or dental sick call.

(3) Permission to be absent.

d. Parking

(1) Where

(2) When

(3) How

e. Visitors and phone calls

(1) Emergencies only.

(2) Phone numbers

(a) School number

f. Lost or damaged material

(1) Text books

(2) Publications

(3) Tools

(4) Materials

(5) Statement of charges

g. Clean-up procedures

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

- h. Problems
  - (1) Scholastic
  - (2) Personal
  - (3) Counseling assistance
- 4. Standards of student performance
  - a. Written examinations
  - b. Homework assignments
  - c. Practical application
- 5. Course outline
  - a. Course mission
  - b. Course objectives
  - c. Reading assignments
  - d. Class schedule
- 6. Grading system
  - a. Homework
  - b. Practical application
  - c. Quizzes
  - d. Weekly tests
  - e. Final examination

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
B. Safety		
1. Reporting accidents		
a. Class safety man	B.1.a. Pick safety man and explain job.	
b. Instructor		
c. School director		
d. First aid when appropriate.		
2. Fire safety		
a. Evacuation routes		
b. Reporting fires		
c. Fighting fire		
(1) Location of extinguishers.		
III. APPLICATION:		
A. Discussion	III.A. Questions To be developed by the instructor.	III.A. Answers
IV. SUMMARY:		
A. Introduction		
1. Mission		
2. Organization and Chain of Command		
3. Regulations and Policies		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
4. Standards		
5. Course Outline		
6. Grading System		
B. Safety		
1. Reporting accidents		
2. Fire safety		
V. TEST:		
A. None		

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

Classification: Unclassified

Topic: Lettering

Average Time: 2 Periods (Class) 2 Periods (Pract)

Instructional Materials:

A. Texts:

1. Engineering Aid 3 & 2, NAVPERS 10634-B
2. Engineering-Technical Drafting & Graphics.

B. References:

1. Architectural Drawing & Light Construction.
2. Drawing and Specifications, NAVFAC DM-6.
3. Architectural Graphic Standards.
4. MIL-STD-100A.

C. Tools, Equipment and Materials:

1. Equipment.
    a. T-square.
    b. Triangle.
        (1) 30° /60°.
        (2) 45°

Terminal Objective: At the completion of this unit the student will be able to use the tools of a draftsman and perform the techniques and procedures related to basic drafting. All problem solutions submitted by the students as his finished product will meet the minimum requirements of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1.

Enabling Objectives: Upon completion of this topic the student will be able to complete two freehand lettering exercises using single-stroke Gothic-style lettering of proper size, spacing, and opaqueness. Individual instructor guidance, commercial lettering books, and examples of notations made on sample drawings may be utilized in the performance of the requirements of this topic. The lettering exercises submitted by the students as his finished product will meet the acceptable standards of SCBT 420.1 EA EG 1.2.0.1 for uniformity, size, spacing of letters, words and sentences, and opaqueness.

Criterion Test: The student will demonstrate his ability to letter freehand and using a lettering set by completing the requirements of Job Sheet SCBT 420.1 EA JS 1.2.1.1 "Freehand and Mechanical Lettering".

Homework: None

c. French curve.

d. Scales.

  (1) Civil engineers.

  (2) Architects.

e. Drafting set.

f. Erasing shield.

g. Lettering guide.

h. Dusting brush.

i. Pencil pointer.

j. Lead holder.

k. Drawing table.

l. Templates.

  (1) ABC.

  (2) Circle.

  (3) Isometric.

m. Protractor.

n. Ames lettering set.

o. Leroy lettering set.

2. Materials.
    - a. Drawing pencils (assorted).
    - b. Drawing paper.
        - (1) Tracing paper.
        - (2) Coordinated paper.
    - c. Masking tape.
    - d. Erasers.
        - (1) Pink pearl.
        - (2) Art gum.
    - e. Drawing leads.
        - (1) H
        - (2) HB
        - (3) F
        - (4) 2H
        - (5) 4H
    - f. Drafting ink.

D. Training Aids and Devices:

1. Slides.
    - a. 65618 - Scales, Set 3
    - b. 65619 - Compass and Bow Instruments, Set 3.

c. 65620 - Freehand Lettering, Set 3.

2. Transparencies.

   a. 11CS-10290.101T-1 T-square, Jacobs, and Drafting Machine.

   b. 11CS-10290.104T-1 Variations of Ruling Pens.

3. Locally Prepared Materials:

   a. Job Sheet.

      (1) SCBT 420.1 EA JS 1.2.1.1 "Freehand and Mechanical Lettering".

   b. Evaluation Guide.

      (1) SCBT 420.1 EA EG 1.2.0.1

4. Training Aids Equipment:

   a. Projectors.

      (1) Overhead.

      (2) 35mm slide.

      (3) 16 mm movie.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name.		
2. Topic: Lettering.		
B. Establish Readiness.	I.B. Bring out need and value of material being presented.	I.B. Participate in class discussion.
1. Relate to the need of lettering.		
2. Leroy lettering is used extensively.		
C. Establish effect.	I.C. State that first portion of lecture will include introduction to tools, equipment, materials, and procedures used by draftsmen.	
1. Lettering can make or break a job.		
2. Mechanical aids can be quite a time saver.		
D. Overview.	I.D. Instruct students to take notes either using handouts or scratch paper.	
1. You will be able to:		
a. Letter freehand using proper letter shape, spacing, slants, uniformity, and neatness.	I.D.4. Instruct students to take notes either using handout or scratch paper.	
b. Letter mechanically, using a lettering set, meeting the same requirements as for freehand lettering.		
2. Ask questions.		
3. Take notes.		
4. Testable information.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
II. Presentation.		
A. Text.		
1. Definition.		II.A.1. Incorporate additional learning senses by participating in discussion and by taking notes.
a. A book used as a standard work or basis of instruction in any branch of knowledge.		
2. Examples.	II.A.2. Show each text and briefly explain organization.	
a. Engineering Aid 3 & 2.		
b. Drafting and Graphics.		
B. Standards.		
1. Definitions.		
a. An authoritative model for guidance.		
2. Military Standard.	II.B.2. Show and explain MIL-STD.	
a. 100-A Drawing Practices.		
3. Civilian Standards.		
a. Architectural Graphic Standards.		
C. References.		
1. Definition.		
a. A publication consulted to identify certain facts or for background information.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
2. Examples.	II.C.2. Give name, material coverage, and use of each reference.	
a. Building Construction Handbook.		
b. Fundamentals of Carpentry.		
c. Asphalt Handbook.		
d. Portland Cement Association Handbook.		
e. AISC Manual of Steel Construction.		
D. Drafting Equipment.	II.D. Introduce the student to equipment that will be used in class environment under "care" teach checking instrument. Show T-square & triangle slides SN34-A.	II.D. Handle each equipment item as instructor describes.
1. T-square.		
a. Type.		
b. Material.		
c. Uses.		
d. Care.		
2. Triangles.	II.D.2. Identify the 45° 30° / 60° and the adjustable triangles.	
a. Type.		
b. Material.		
c. Uses.		
d. Care		
3. Curves.		
a. Type		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
b. Material.		
c. Uses.		
d. Care.		
4. Scales.	II.D.4. Show slide #65618, "Scales" Set 3.	
a. Type.		
b. Material.		
c. Uses.		
d. Care.		
5. Drafting set.	II.D.5. Show slide "Compass and Bows" Set 3, No 65619.	
a. Contents.		
(1) Use.		
(2) Care.		
6. Erasing shield.		
a. Material.		
b. Uses.		
7. Lettering guides.	II.D.7. Handout instructions for the Lettering Guide.	
a. Types		
b. Material.		
c. Uses.		
d. Care.		

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

8. Bench brush.
    a. Material.
    b. Use.
9. Pencil pointer.
    a. Types
10. Lead holder.
    a. Use.
11. Drawing table.
    a. Types.
    b. Material.
    c. Use
    d. Care.
12. Templates.
    a. Types
    b. Material.
    c. Use.
    d. Care.
13. Protractors.

II.D.9. Show sandpaper pad and mechanical pencil.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

- a. Types.
- b. Material.
- c. Use.
- d. Care.

E. Drafting Materials.

1. Pencils and leads.
    - a. Type
    - b. Grade.
    - c. Use.
2. Drawing paper.
    - a. Tracing.
        - (1) Type.
        - (2) Use.
    - b. Coordinate paper.
        - (1) Type.
        - (2) Use.
3. Tape.
    - a. Type.
    - b. Use.

II.E. Give the students the recommended: F, H, 2H, 3H, 4H, construction drafting 4B, 3B, 2B, B, and HB - rendering. HB, F, H, and 2H lettering.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
4. Erasers.		
a. Type		
b. Use.		
5. Ink.		
F. Preparation.	II.F. State that the light should come from left and measure 80-100 candle power.	
1. Drafting table.		
a. Lights.		
b. Board.	II.F.b. State that board should be inclined 10-18°.	
c. Instruments.		
d. Paper.		
e. Pencils.	II.F.e. State some grades of pencils that should be available.	
G. Formats.		
1. Paper size.	II.G.1. Give demonstration on folding drawing.	
a. Flat.		
b. Roll.		
c. Stowage.		
2. Title block.	II.G.2. Explain the standard title block.	
a. Security.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
H. Alphabet of Lines.	II.H. Use stick file. Have student identify each convention. Demonstrate hidden line conventions on C/B.	II.H. Take a set of drawings from stick file. Point out the line convention on the prints. Draw each convention on a piece of paper.
I. Practices.		
1. Read assignment.		
2. Layout of drawing.	II.I.2. Pass out Evaluation Guide SCBT 420.1 EA EG 1.2.0.1 and cover each item.	
a. What is a good drawing.		
(1) Visible lines.		
(2) Dimensions		
(3) Notes.		
(4) Line conventions.		
(5) Tangents.		
(6) Format.		
(7) Lettering.		
(8) Numerals & Fractions.		
(9) Accuracy.		
(10) Solution.		
3. Order of drawing.		
a. Pencil.		
b. Ink.		

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

4. Simplified drawing practices.

J. Lettering (freehand).

1. Definition.

    a. Presentation of informational data on a drawing.

2. Four styles of lettering.

    a. Roman.

    b. Gothic.

    c. Script.

    d. Text (old English)

3. Single-stroke Gothic.

    a. Style.

        (1) Vertical.

        (2) Inclined.

            (a) 67-1/2°

    b. Composition.

        (1) Opaque.

        (2) Strokes.

        (3) Proportions.

        (4) Spacing.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(a) Letters.		
(b) Words.		
(c) Sentences.		
(5) Lines.		
c. Height.		
(1) MIL-STD recommendations.		
d. Guide lines.		
e. Pencils.		
4. Technique of execution.		
a. Vertical stroke.		
b. Horizontal strokes.		
c. Curved strokes.		
K. Lettering (Mechanical).	II.K. Have students break out Leroy lettering sets.	II.K. Break out Leroy lettering sets.
1. Definition.		
a. Lettering done with:		
2. Types of devices or aids:		
a. Leroy.		
b. Unitech.		
c. Varityper.		

- (1) Typewriter
- (2) Headliner.

d. Artype.

- (1) Format.
- (2) Prestyle.

3. Leroy
   - a. Parts.
   - b. Templates.
   - c. Styles.
   - d. Uses.
4. Unitech.
   - a. Parts.
   - b. Templates.
   - c. Styles.
   - d. Uses.
5. Varityper.
   - a. Typewriter.
     - (1) Parts.
     - (2) Styles.
     - (3) Uses.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
b. Headliner.		
(1) Parts.		
(2) Styles		
(3) Uses		
6. Artype (Pressure sensitive)		
a. Format	II.K.6.a. Demonstrate how to use format by using overhead projector.	
(1) Styles		
(2) Uses		
b. Prestyle	II.K.6.b. Demonstrate how to use prestyle by using overhead projector.	
(1) Styles		
(2) Uses		
7. Techniques of execution.		
a. Composition		
b. Spacing		
c. Guide lines		
III. Application		
A. Questions and Discussion	III.A. Questions.	III.A. Answers.
	1. What are the two commonly used triangles?	1. 45° and 30°/60°

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
	2. Why do good draftsmen always use a lettering guide?	2. To keep letters uniform in height.
	3. What is the difference between the architect's & the engineering scale?	3. Architect is common fractions & engineer is decimal.
	4. What is the minimum light requirements for a drafting room?	4. 80-100 candle power.
	5. What is the size of a "C" sheet?	5. 17 x 22.
	6. What are the medium weight lines on a drawing?	6. Hidden lines, phantom lines & stitch lines.
	7. What is the first step in doing any job?	7. Read assignment.
	8. What type of lettering is never used in engineering drawing?	8. Lower case.
	9. What instrument is used for spacing guide lines?	9. Ames & Braddock-Rowe lettering instruments.
	10. Which of the five mechanical lettering devices or aids is in most common use?	10. Leroy.
	11. A press-on type lettering aid is called . . . .?	11. Artype

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
B. Practical Performance	III.B. Pass out and explain Job Sheet SCBT 420.1 EA JS 1.2.1.1 "Freehand and Mechanical Lettering".	III.B. Practice lettering and work on job sheet requirements.
IV. Summary.	Guide students in application of lettering. Evaluate student performance on completed work.	
A. Text.		
1. Definition.		
2. Review texts.		
B. Standard.		
1. Definition.		
2. Military Standards.		
3. Civilian Standards.		
C. References.		
1. Definition.		
2. Review references.		
D. Drafting Equipment.		
1. T-Square		
2. Triangle.		
3. Curves.		
4. Scales.		
5. Drafting set.		

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OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

6. Erasing shield.
7. Lettering guide.
8. Bench brush.
9. Pencil pointer.
10. Lead holder.
11. Drawing table.
12. Templates.
13. Protractors.

E. Drafting Materials.

1. Pencils and leads.
2. Drawing paper.
3. Tape.
4. Erasers.
5. Ink

F. Preparation for Drawing.

G. Drawing Formats.

H. Alphabet of Lines.

I. Drawing Practices

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY

J. Lettering (freehand)

1. Definition.
2. Styles of lettering.
3. Single-stroke gothic.
4. Technique of execution.

K. Lettering (Mechanical)

1. Definition.
2. Types.
3. Leroy.
4. Unitech.
5. Varitypes.
6. Artype.
7. Technique of execution.

V. Test.

A. Job Sheet Completion.

1. Those students who have not satisfactorily completed the requirements of the Job Sheet SCBT 420.1 EA JS 1.2.1.1 "Freehand and Mechanical Lettering" must do so on their own time and turn in same at the start of the next working day.

VI. Assignment

A. Read

1. MIL-STD-100A, General Drawing Practices. Pages 1-23.

2. Drafting and Graphics, Page 1-55.

B. Look for Drawing Techniques and Practices.

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JOB SHEET

TITLE: FREEHAND AND MECHANICAL LETTERING

INTRODUCTION: The purpose of this job sheet is to guide you in the practical work assignment of freehand and mechanical lettering. After assembling the necessary tools and material, read over the procedures rapidly to get a general picture of the lettering requirements, then complete each of the three lettering sheets.

Single-stroke letter is by far the greatest amount of lettering done on drawings, it is done in a rapid single-stroke style lettering. Every engineering aid must have an absolute command of either the vertical or the inclined style. The ability to letter can be acquired by anyone with normal muscular control of his fingers, who will practice faithfully and intelligently, and take the trouble to observe carefully the shapes of the letters, the sequence of strokes in making them, and the rules for their composition. It is not a matter of artistic talent or even of dexterity in handwriting. Many persons who write very poorly letter very well.

REFERENCES:

1. Military Standard, Engineering Drawing Practice, MIL-STD-100A, Page 9.
2. Engineering Aid 3 & 2, NAVPERS 10634B, Page 95.
3. Engineering-Technical Drafting and Graphics, 2nd Edition, Page 41.

TOOLS, EQUIPMENT AND MATERIALS:

1. Drawing board or table.
2. Two sheets "A" size tracing paper.
3. One sheet lettering paper.
4. Ames-style lettering instrument.
5. Drafting tape.
6. Pencils (as necessary).
7. T-square.
8. Eraser.
9. Erasing shield.

10. Lettering set.

11. India ink.

PROCEDURE:

Part 1. "A" size paper, lettering set and ink.
Lay out the paper horizontally in accordance with MIL-STD-100A, Page 9, omit revision and title blocks. Letter the following information in upper case letters using a lettering set. NOTE: USE A LETTER TEMPLATE RANGING FROM 157, 200 or 240 AND THE PROPER PEN SIZE AS DESIGNATED ON THE DIAGRAM ON THE INSIDE COVER OF THE LETTERING INSTRUMENT BOX. Letter your last name in the lower right-hand margin in 5/32 inch high letters.

Part 2. Lettering paper, freehand with paper.
Letter your last name on the top line and complete all lines by lettering freehand in single-stroke, upper case Gothic style using each letter of the alphabet approximately ten (10) times. Letter your name in the lower right-hand margin in 5/32 inch high letters.

Part 3. "A" size paper, freehand with pencil.
Refer to Figure 3-7, Page 41 of Drafting and Graphics. Letter freehand in single-stroke upper case Gothic Style, two examples of each of the seven (7) recommended letter heights, as shown in the right-hand column. For the dimensions, fractional and decimal section, make five (5) fractions as diagrammed. Draw proper borderline in accordance with MIL-STD-100A, Page 9. Omit the title and revision blocks. Letter your last name in the lower right-hand margin in 5/32 inch high letters.

NOTE: In each part of the procedure above, spacing between letters and between words should be in accordance with requirements set forth in Engineering Aid 3 & 2, Page 95.

Complete work must meet the acceptable standards set forth in SCBT 420.1 EA EG 1.2.0.1 for lettering.

QUESTIONS: None

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EVALUATION GUIDE

INTRODUCTION

You can benefit from learning how to evaluate your own drawings. In addition, if you know and understand what is required of you in making good drawings you can check yourself from the start of each drawing to ensure you meet the requirements as set forth in this evaluation guide.

The following guide is broken into ten distinct topics, each with its own description and the basic requirements. The acceptable drawing practices for each topic are listed along with the most common unacceptable practices. It is to your benefit to keep all the drawing practices within the acceptable range, not only because by doing so will enable you to pass the course, but also because it will develop good drawing habits that will aid you in your future career.

Honesty with yourself is essential in order to benefit from this evaluation giude. Your instructor will use this guide to evaluate your work to determine if you have met the objectives of each lesson. Keep in mind that the evaluation guide is a teaching device as well as a check-list of drawing practices. It is only as effective as you and your instructor make it - DO YOUR PART.

DEFINITIONS of some general terms used in this guide.

Fuzzy Lines -	The flaking of pencil lines. More evident when soft leads are used.
Hole/Holes -	The circle, slot, etc. indicated on a drawing that represents a hole in the object.
Line Thickness -	The opaqueness and line width as outlined in MIL-STD-100A, Page 46.
Opaque -	The darkness of an ink or pencil line in relation to how it will reproduce when making copies. Opaque includes the consistent shade over the whole line or shading where used.
Reproduction-	The use of the original tracing paper or vellum drawing to make copies, usually by the Diazo process.

I

VISIBLE LINES

References: MIL-STD-100A, pp. 28-30, 46
Drafting and Graphics, pp. 26-28

Visible lines define the outline or visible detail of an object. They are heavy unbroken lines of uniform width and have the same degree of opaqueness or blackness through all visible lines used on a specific drawing. Care must be taken to ensure that visible lines are opaque and give a continuous solid line when reproduced.

Acceptable Standards	Unacceptable Standards
1. Opaque, that will reproduce well.	1. Line of various thickness
2. Sharply drawn lines.	2. Fuzzy lines
3. Uniform opaqueness.	3. Over-run or nonconnecting intersections.
4. Distinct intersections.	4. Not properly located.
5. Properly located.	5. Not opaque enough to reproduce.

II

DIMENSIONS

References: MIL-STD-100A, pp. 29, 45-46
USASI Y14.5-1966
Drafting and Graphics, pp. 110-146, 511-512
Architectural Drawing and Light Construction, pp. 191-194

Dimensions or dimensioning is the numerical value expressed in units of measure used on drawings in conjunction with lines, symbols and notes to define the characteristics or shape of an object. Dimensioning encompasses extension lines, dimension lines, arrowheads, and completeness of information.

Acceptable Standards	Unacceptable Standards
1. Thin extension lines.	1. Thick or light dimensions and/or extension lines.
2. Extension lines 1/16 inch away from visible lines.	2. Broken dimension lines.
3. Proper spacing between dimension lines.	3. Poor spacing of dimension lines.
4. Uniform arrowheads, proper proportion.	4. Arrowheads not uniform or proper shape.
5. Numerals spaced for ease of reading.	5. Missing numerals, hole information, radii, or diameter notations.
6. Dimensions read from the bottom and right-hand side of drawing.	6. Dimension read from the top or left-hand side of drawing.
7. Proper notation of holes.	7. Dimension not opaque enough to reproduce.
8. Proper orientation of notations for radii and diameters.	

III

NOTES

References: USASI Y14.5-1966
Drafting and Graphics, pp. 132, 135, 512
Architectural Drawing and Light Construction, pp. 194-195

Notes on drawings are used to supply information which cannot be given in other ways or which requires a description. Notes are used for a variety of purposes and allow draftsmen flexibility in their descriptive application on drawings. Notes encompass leaders, arrowheads, and completeness of information.

Acceptable Standards	Unacceptable Standards
1. Give complete information.	1. Incomplete notes.
2. Leaders drawn at 30/45/60 degree angles with the horizontal.	2. Leaders drawn at random angles.
3. Notes kept close to the view in which information is required.	3. Notes separated from the view in which information is required.
4. Leaders point to centers of circles, arcs and holes.	4. Leaders not aligned with centers of circles, arcs and holes.
	5. Misspelled information.

IV

LINE CONVENTIONS

References: MIL-STD-100A, pp. 45-49
Drafting and Graphics, pp. 26-29

Line conventions are concerned with all lines except visible lines, dimensions, extension, and leader lines covered in Topics I, II, III, that are used to fully describe an object according to established drawing practices.

Acceptable Standards	Unacceptable Standards
1. Line conventions used appropriately.	1. Dashes thick and/or fuzzy.
2. Lines properly drawn.	2. Hidden lines connect with visible lines.
3. Lines opaque enough to reproduce, except construction lines.	3. Lines not opaque enough to reproduce.
4. Some degree of fuzziness is allowed for thin lines.	4. Lines incorrectly drawn and/or located.
5. Construction lines very lightly drawn and may remain on finished drawing.	5. Line consistency varies.

V

TANGENTS

References: Drafting and Graphics, pp. 23, 62-66, 75, 77
Architectural Drawing and Light Construction, pp. 41-42

A tangent is an intersection of a straight line and a curved line or the intersection of two curved lines. The most common tangents in drawings are found in fillets and rounds that come into contact with visible lines or straight lines and curves or ogee curve. There are few applications in drafting where tangents are not used.

Acceptable Standards	Unacceptable Standards
1. Tangents perpendicular to radii.	1. Tangents not accurately drawn or perpendicular to radii.
2. Radii extend through point of tangency.	2. Uneven tangency.
3. Straight lines and curved lines of one thickness.	3. Tangency not complete or do not meet.
4. Lines meet as one smooth, continuous line.	

VI

FORMAT

References: MIL-STD-100A, pp. 4-13
DM-6, pp. 6-1-4 thru 6-1-14
Drafting and Graphics, pp. 90-99, 506-533

The format of a drawing is the overall layout of the drawing. The format includes how the views are spaced, the accuracy of the borders and title block, and the overall neatness and appearance of the finished work.

Acceptable Standards	Unacceptable Standards
1. Layout of borders, title block, etc., according to standards and job sheet instructions.	1. Object orientation not balanced, poor appearance.
2. Object is oriented for a pleasing effect.	2. Border and/or title block not according to standards or job sheet instructions.
3. Views chosen according to best representation of object.	3. Views chosen not best representation of object.
4. Title block annotated with required information.	4. Spacing between views too wide.

VII

LETTERING

References: MIL-STD-100A
Engineering Aid 3 & 2, pp. 92-100
Architectural Drawing and Light Construction, pp. 23-38

Lettering presents the information data on a drawing whether the information is in the form of dimensioning, explanatory notes or the listing of specifications, the lettering must be legible and pleasing in appearance.

Acceptable Standards	Unacceptable Standards
1. Uniform in size and shape.	1. Uneven letters.
2. Spacing by shape of letters.	2. Uneven spacing of letters or of mechanical appearance.
3. Even spacing of words.	3. Uneven spacing of words.
4. Words smooth in appearance.	4. Vertical stems not uniform.
5. Opaque letters.	5. Variable opaqueness, poor reproduction quality.

VIII

NUMERALS AND FRACTIONS

References: Engineering Aid 3 & 2, pp. 92-97
Drafting and Graphics, p. 43
Architectural Drawing and Light Construction, pp. 22-38

Numerals and fractions apply to all numerical information on a drawing and are a vital element in accurately describing the object drawn.

	Acceptable Standards		Unacceptable Standards
1.	Spacing between numerals and fractions.	1.	Numerals and/or fractions too heavy, filled in.
2.	Distinct numerals, easily read.	2.	Numerals/fractions run together.
3.	Fractions slightly larger than numerals.	3.	Carelessly made figures.
4.	Distinctly formed figures.	4.	Numerals larger or same size as fractions.

IX

ACCURACY

References: None

Accuracy is the condition or quality of being accurate, precise, exact or correct. Accuracy is determined by how well a drawing is scaled, layed out, and annotated to give a clear, concise picture of what is represented.

Acceptable Standards	Unacceptable Standards
1. Figure size within ± 1/32"	1. Figure size ± 1/16" or over.

X

SOLUTION

References: None

Solution is the act of solving a problem. In drafting, the solution is the representation of an object of features using the proper methods, orientation, terminology, etc., combined to make a complete presentation.

Acceptable Standards	Unacceptable Standards
1. Drawing made by the student only.	1. Help needed on majority of the drawing.
2. Solution made with minimum aid from other students or instructor.	2. More than two efforts made to solve the problem.
3. Use of only one clue from the instructor to solve the problem.	3. Copying from a finished product or partial product.

NAVAL CONSTRUCTION TRAINING CENTER
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Classification: Unclassified

Topic: Technical Sketching

Average Time: 1 Period (Class) 5 Periods (Pract)

Instructional Materials:

A. Texts:

1. Engineering-Technical Drafting & Graphics, 2nd Edition, Chapter 16.

B. References:

1. Technical Drawing, by Giescke, Mitchell, & Spencer, 4th Edition, Chapter 5.

2. Architectural Drawing & Light Construction, by Muller, Chapter 5.

3. Engineering Drawing, by French & Vierck, 10th Edition, Chapter 6.

C. Tools, Equipment and Materials:

1. Coordinated paper, 10 x 10, 8½ x 11.

2. Tracing paper.

   a. 8½" x 11"

   b. 11" x 17"

Terminal Objective: Upon completion of this unit the student will be able to use the tools of a draftsman and perform the techniques and procedures related to basic drafting. All problem solutions submitted by the student as his finished product will meet the minimum requirements of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1

Enabling Objective: Upon completion of this topic the student will be able to make freehand technical sketches from objects, notes and verbal descriptions that can be used to develop descriptive construction and shop drawings. Student texts, commercial technical sketching publications, and the guidance of the instructor may be utilized in the performance of the requirements of this topic. All sketches submitted by the student as his finished product will be of proper proportion to represent the object sketched and contain opaque visible lines as well as proper shading or rendering sufficient enough to make a legible Diazo reproduction.

Criterion Test: The student will demonstrate his ability to make technical freehand sketches by accomplishing the requirements of Job Sheet SCBT 420.1 EA JS 1.2.2.1, "Technical Sketching".

Homework: Read

Engineering-Technical Drafting and Graphics, 2nd Edition, Chapter 16, pp. 490-505.

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3. Drawing pencils.

D. Training Aids and Devices.

1. Film

a. MC-6797-C, Pictorial Sketching.

2. Locally Prepared Material.

a. Job Sheet

(1) SCBT 420.1 EA JS 1.2.2.1
"Technical Sketching".

E. Training Aids Equipment:

1. Projectors.

a. 16 mm motion picture.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name.		
2. Topic: Technical Sketching.		
B. Establish readiness.	I.B. Get students ready to learn.	I.B. Participate in class discussion.
1. A valuable means of expression.		
2. "One picture is worth a thousand words".		
C. Establish effect.	I.C. Bring out value of sketching.	
1. Value.		
a. On many jobs a sketch is all that is necessary to accomplish the work.		
b. Often you will be required to draw without proper equipment.		
D. Overview:		
1. You will be able to make technical freehand sketches following procedures set forth in Drafting and Graphics, Chapter 16.		
2. Ask questions.		
3. Take notes.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
II. Presentation.		
A. Importance of Technical Sketching.	II.A. Show film MC-6796-C Pictorial Sketching.	
1. Original ideas.		
a. First expression.		
2. Organize thoughts.		
a. Record of ideas.		
3. Degree of perfection.		
a. Depends upon its use.		
B. Materials.		
1. Paper.		
a. Cross-section paper.	II.B.1.a. Point out the ease in drawing on cross-section paper and stress good proportion.	
(1) 10" x 10".		
(2) 8" x 8".		
(3) Pictorial.		
(a) Isometric.		
2. Pencils.		
a. Selected according to requirements of sketch.	II.B.2.a. Point out to sharpen in normal manner, except when shading is desired.	
(1) Rough sketches, ideas, renderings - 6B, 5B, 4B.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(2) Machine details - 3B to HB.		
(3) Critical work and detail - F to 2H.		
(4) On smooth paper - F to H.		
b. Harder than 2H.		
(1) Seldom used.		
3. Erasers.		
a. Artgum.		
b. Pink Pearl.		
C. Types of sketches.		
1. Multi-view projection.	II.C.1. Write on C/B.	
a. All necessary views.		
2. Single-view projection.		
a. Pictorial.		
(1) Isometric.		
(2) Oblique.		
D. Scale.		
1. Correct proportions.		
a. Accurately.		
2. Cross-section paper.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
a. Ready scale.		
3. Small objects.		
a. Drawn oversized.		
E. Techniques.		
1. Quality of a freehand line.		
a. Freedom.		
b. Variety.		
2. Alphabet of lines.		
a. Same as mechanically made.		
b. Dark and opaque.		
c. Clean-cut.		
3. Position of pencil.		
a. 1 1/2" to 2" from point.	II.E.3.a. Demonstrate on C/B.	
b. Rotate slightly.		
c. Slant from 50° to 60° from vertical for straight lines.		
d. 30° for circles.		
e. Lean pencil in direction of travel.		
4. Straight lines.	II.E.4. Demonstrate on C/B.	II.E.4. Practice on a sheet of paper.
a. Short lines.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(1) Finger action.		
b. Long lines.		
(1) Wrist or forearm.		
(2) Series of short strokes (1 1/2" to 2" long.)		
c. Keep eye on point to which line must travel.		
(1) Never on pencil.		
d. Lightly complete line before darkening.		
e. Accuracy in direction is more important than smoothness.		
5. Circles and arcs.		
a. Small circles and arcs.	II.E.5.a. Demonstrate on C/B.	II.E.5.a Practice on a sheet of paper.
(1) One or two strokes.		
b. Steps for large circles.		
(1) Extend center lines and additional radii.		
(2) Mark points on these extensions.		
(3) Sketch short arcs and complete.		
c. Alternate method.		
(1) Sketch lightly the enclosed square.		
(2) Mark the mid-points of the sides.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(3) Draw light arcs tangent to sides.		
(4) Heavy-in final circles.		
6. Proportions.		
a. Most important rule.		
(1) Sketch in proportion.		
b. Constantly compare each new line.		
c. "Squares method".		
(1) Enlarging or reducing.		
(2) Grid made at any convenient size.		
(3) Estimate by bye-crossing of grids.		
d. Blocking-in method.	II.E.6.d. Demonstrate on C/B.	
(1) Block-in views.		
(2) Build-up detail.		
(3) Brighten outline.		
(4) Brighten details.		
(5) Brighten hidden features.		
(6) Check drawing.		
7. Shading.	II.E.7. Illustrate effects of light on simple shapes by using overhead transparencies showing basic forms.	
a. Use light and dark.		

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(1) Surfaces appear to advance while others appear to recede.

b. Location of light.

(1) Usually from upper-left position.

c. Reflected light.

(1) From surrounding objects.

(2) Surfaces lightened beyond the shaded edge.

d. Highlight.

(1) Whiten areas.

(2) Parallel highlights for cylindrical surfaces.

(3) Overhangs, recesses, etc. require shadows to reveal their relief.

e. Contrast.

(1) Light to dark for junctions.

(2) Dark tones.

(3) Light tones.

(4) Stippling.

(5) Shaded lines reveal form of the surface.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

F. Viewing of Objects.

1. Multi-view projection.

a. View taken in a direction perpendicular to a principal face or side.

(1) Take view of shape and size.

b. Three principal dimensions.

(1) Width.

(2) Height.

(3) Depth.

c. Revolving the object.

II.F.1.c. Take an object and revolve as explaining.

(1) Top view - top of object.

(2) Right-side view - right side of object.

(3) Any other view - rotate object.

d. Three regular biews.

(1) Top.

(2) Front.

(3) Right side.

e. Hidden features.

(1) Hidden lines.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
f. Choice of views.		
(1) Eliminate unnecessary views.		
(2) Two-view drawings.		
(3) Should be chosen that show features with visible lines.		
g. Center lines.		
(1) Indicate axis of symmetrical objects.	II.F.1.g.(1) Show a typical application.	
h. Alignment of views.		
(1) Top view directly above the front view.		
(2) Right-side view directly to the right of front view.		
(3) Never draw the views in reversed position.		
2. Single-view projection.		
a. Isometric.		
(1) View taken of the object rotated and tilted toward viewer.	II.F.2.a.(1) Demonstrate.	
(2) Isometric axis.		
(a) 30° with horizontal.		

OUTLINE OF INSTRUCTION | INSTRUCTOR ACTIVITY | STUDENT ACTIVITY

(3) Box construction.

(4) Ellipses

- (a) Major axis at right angles to the center line.
- (b) Minor axis at right angles to the major axis coincidental with center lines.
- (c) Box construction.
- (d) Four-centered method.

(5) Isometric paper.

- (a) Coordinated grids.

b. Oblique.

II.F.2.b Demonstrate.

(1) Types.

- (a) Cavalier.
- (b) Cabinet.

(2) Oblique axis.

- (a) 30° or 45° with horizontal.
- (b) Full scale - cavalier.
- (c) Half size receding surfaces - cabinet.

(3) Front face.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(a) View taken in a direction perpendicular to the principal face.		
(4) Coordinated paper.		
III. Application		
A. Questions and Answers	III.A Questions	III.A Answers
	1. Why is it a good idea to sketch the drawing first?	1. Aid in layout.
	2. What type of projection is usually used to gain a better overall picture?	2. Pictorial.
	3. What should your eyes be doing when drawing a long line?	3. Be on the point ahead of the line.
B. Practical Application.		
1. Introduce Job Sheet.	III.B.1. Hand out Job Sheet and go over with students.	III.B.1 Follow along with explanation.
a. SCBT 420.1 EA JS 1.2.2.1 "Technical Sketching".		
2. Practice exercise.	III.B.2 Assist students.	III.B.2. Accomplish requirements of job sheet.
IV. Summary		
A. Importance of Technical Sketching.		
B. Materials		
1. Paper		
2. Pencils		

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

    3. Erasers

  C. Types of Sketches.

    1. Multi-view projection.

    2. Single-view projection.

      a. Pictorial.

  D. Scales

  E. Techniques.

    1. Quality

    2. Alphabet of lines.

    3. Position of pencil.

    4. Straight lines.

    5. Circles and arcs.

    6. Proportions.

    7. Shading.

  F. Viewing of Objects.

V. Test:

  A. Complete the requirements of Job Sheet SCBT 420.1 EA JS 1.2.2.1

SCBT 420.1 EA JS 1.2.2.1

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

JOB SHEET

TITLE: BASIC TECHNICAL SKETCHING

INTRODUCTION: The purpose of this job sheet is to guide you in the practical work assignment of sketching. After assembling the necessary tools and materials, read over the procedures rapidly to get a general picture of the sketching requirements.

REFERENCES:

1. Architectural Drawing and Light Construction, pp. 69-78.

2. Military Standard, Engineering Drawings Practices, MIL-STD-100A, pp.9

TOOLS, EQUIPMENT AND MATERIALS:

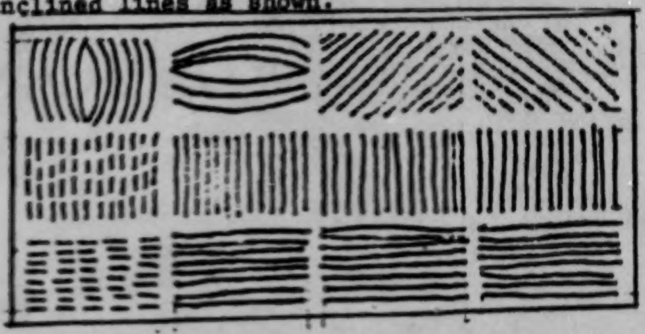
1. 3 sheets 10" x 10" coordinate paper, 8½ x 11".

2. Pencils.

PROCEDURES: Draw the following problems on an "A" size sheet of coordinate paper laid out in vertical format in accordance with MIL-STD-100A, Page 9. On your finished drawing place your last name in the lower right-hand margin in 5/32" high letters. Omit title block and revision block. Make a print of your finsihed sketches following Job Sheet SCBT 420.1 EA JS 1.2.2.1.

PROBLEM #1 (Fig. 5-41, pp 90, Architectural Drawing & Light Construction; Ref:)

Layout a border and divide the paper into twelve equal rectangles freehand as shown. With an HB pencil carefully fill the rectangles with horizontal, vertical and inclined lines as shown.

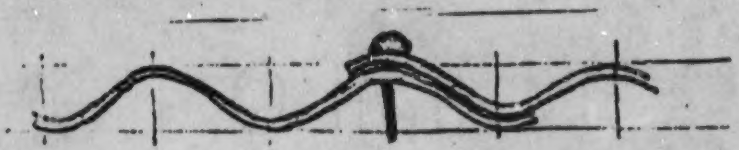


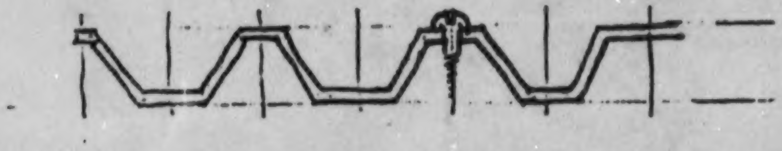
PROBLEM #2 (Fig. 5-42, pp 91, Architectural Drawing & Light Construction; Ref:)

Sketch a 3" square and bisect each side by eye. Connect the points to form an inverted square within the original, continue drawing squares within squares until space is filled.

PROBLEM #3 (Fig. 5-19 pp. 76, Architectural Drawing & Light Construction; Ref:)

Sketch the corrugated metal sections, as shown.





Completed drawings must meet acceptable standards of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1 for visible lines, format and instructor requirements for proportion and solution.

QUESTIONS: None

SCBT 420.1 EA IG 1.2.3

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 90343
SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

Classification: Unclassified

Topic: Geometric Construction

Average Time: 3 Period (Class) 5 Period (Pract)

Instructional Materials:

A. Texts:

1. Engineering Aid 3 & 2, NAVPERS 10634-B
2. Engineering - Drafting and Graphics, Second Edition.

B. References:

1. Architectural Drawing & Light Construction.
2. Engineering Drawing by French and Vierck, 10th Edition.
3. General Drafting, TM5-230.

C. Tools, Equipment and Materials:

1. Equipment.
    a. T-Square.
    b. Traingles.
        (1) 45°
        (2) 30° - 60°

Terminal Objective: Upon completion of this unit the student will be able to use the tools of a draftsman and perform the techniques and procedures related to basic drafting. All problem solutions submitted by the student as his finished product will meet the minimum requirements of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1.

Enabling Objective: Upon completion of this topic the student will be able to construct two plane geometric figures that include circular and curved surfaces by using standard drafting instruments. Textbooks, other drafting publications, and instructor guidance may be utilized in the performance of the requirements of this topic. Templates may not be used in the completion of the requirements of this topic. All figures submitted by the student as his finished assignment will meet the acceptable standards of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1, for visible lines, tangents, format, accuracy and solution and of an opaque-quality sufficient enough to make a legible Diazo reproduction.

Criterion Test: The student will demonstrate his ability to draw geometric construction by completing the requirements of Job Sheet SCBT 420.1 EA JS 1.2.3.1, "Geometric Construction".

HOMEWORK: Read

Drafting & Graphics, Ch.4 pp. 56-82.

Engineering Aid 3 & 2, Ch.4, pp. 101-121.

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OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

   c. Scales-Architectural & Engineering.

   d. Drafting set.

   e. Dusting brush.

  2. Material.

   a. Masking tape.

   b. Eraser.

   c. Erasing shield.

   d. Drawing pencils.

   e. Typing paper, 8½" x 11", 6 sheets per student.

   f. Tracing paper, 8½" x 11", 2 sheets per student.

D. Training Aids and Devices:

  1. Slides (35mm)

   a. Geometric Construction -SN-35A.

   b. Compass and bow instruments, Set 3, 65619.

  2. Transparencies:

   a. 11CS-1551-115T-4 "Constructing a Regular Hexagon"- Across the Flats.

   b. 11CS-1551-115T-7 "Circle Tangent to a Given Line Passing Through a Given Point".

   c. 11CS-1551-115T-9 "Constructing a Reverse Curve (Ogee)".

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

d. 11CS-1551-115T-8 "Constructing an Ellipse" 4-Center Method.

e. 11CS-1551-115T-6 "Constructing an Irregular Polygon", -Given One Side.

f. 11CS-1551-115T-5 "Constructing an Octagon in a Square".

g. 11CS-1551-115T-2 "Constructing Parallel Lines".

h. 11CS-1551-115T-3 "Constructing a Hexagon - Across Corners".

i. 11CS-1551-115T-11 "Bisecting an Angle".

j. 11CS-1551-115T-1 "Dissecting a Line".

3. Locally Prepared Materials:

a. Job Sheet.

(1) SCBT 420.1 EA JS 1.2.3.1
"Geometric Construction".

E. Training Aids Equipment.

1. Projector.

a. 35 mm slide.

b. Overhead.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name.		
2. Topic: Geometric Construction.		
B. Establish readiness.	I.B. Motivate student.	
1. Purpose: Practical Use of Instruments.		
2. Assignment: Will do geometric design.		
C. Establish effect.	I.C. Bring out need and value of material being presented.	
1. Value.		
a. Pass course.		
b. Perform better on the job.		
c. Get advanced.		
d. Be a better Engineering Aid.		
D. Overview:	I.D. State learning objectives.	
1. You will be able to draw geometric figures and use geometric construction in solving drafting problems.	I.D.1. State information and materials necessary to guide student.	
2. Ask questions.		
3. Take notes.		
4. Testable.		

OUTLINE OF INSTRUCTION

II. Presentation

A. Compass and Bow Instruments.

1. Similar instruments.

2. Compasses.

a. For radius less than 2 inches.

b. Size is determined by distance from top of handle to bottom of leg.

c. Can be used with various weight lead.

d. Sharpen lead before using.

e. Set needle at proper length.

(1) Needle should penetrate paper slightly.

f. Steps in constructing a circle/arc.

(1) Set off radius (measure).

(2) Set needle at position center is to be located.

(3) Use thumb and forefinger to swing circle/arc.

(a) Incline slightly toward direction of rotation.

(b) Complete circle/arc with a continuous motion.

INSTRUCTOR ACTIVITY

II.A. Slides. First section 33 slides.

NOTE: Instructors can also use C/B and equipment for student demonstration vice slides.

STUDENT ACTIVITY

OUTLINE OF INSTRUCTION

g. Use beam compass for larger circles/arcs.

h. Discuss care of instruments.

3. Dividers.

   a. Some bow instruments are interchangeable either compass or divider.

   b. Used to transfer distance from one place to another.

   c. Steps in using dividers.

      (1) Set distance (measure) place dividers at that distance transfer measurements to drawing.

      (2) Dividing a line in equal parts.

         (a) Approximate divisions set dividers.

         (b) Walk off distances.

         (c) Adjust difference at end.

         (d) Walk off again until accurate.

5. Bisecting lines and angles.

   1. Bisect a line (also the same method for bisecting an arc).

      a. Set off line AB.

      b. Set the compass for any radius greater than 1/2 of AB.

INSTRUCTOR ACTIVITY

II.B.1. Distribute typing paper (6 sheets to each student). Instruct students on placing paper on board.

Instruct students to divide paper into two (2) sections

STUDENT ACTIVITY

II.B.1. Students fasten sheets to board.

Divide paper into two (2) sections with pencil lines

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
c. Using A and B as centers, draw two arcs to intersect at C and D.	with pencil lines.	Draw figure following instruction in one of the two sections.
d. Connect points C and D with a light line, where line CD intersect AB, is the center of AB.		
2. Bisect an angle.	II.B.2. Show transparency 11CS-1551-115T-11, "Bisecting An Angle".	II.B.2. Draw figure following instruction in remaining section of paper.
a. Given angle ABC.		
b. With "A" as center and the compass set at any convenient radius, draw an arc cutting line "AB" at "D" and line "AC" at "E".		
c. Set the compass at "A" radius greater than 1/2 of "DE".		
d. With "D" and "E" as centers, draw two arcs to intersect at O.		
e. Draw a line from "A" to O. The line "AO" bisects the angle.		
C. Dividing a Line into any number of Equal Parts.	II.C. Have student remove sheet from board.	II.C. Remove sheets from board.
1. Assume a given line is to be divided into six equal parts.	II.C. Show Transparency 11CS-1551-115T-1, "Dividing a Line".	
2. Draw the required line "AB" which is to be divided.		
3. From one end of this line at point "A", draw line "AC" at any convenient angle.	II.C.1. Instruct student to fasten second sheet to drawing board, divide sheet into two (2) sections.	II.C.1. Fasten second sheet to board, divide into two (2) sections.
4. Starting at "A" on line "AC" lay off six equal spaces with either dividers or scales.		II.C.3. Draw figure following instruction in first section of paper.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
5. From the termination point, "D", of the last space, draw "A" line connecting "D" and "B".		
6. With T-square and triangle, set the triangle parallel with line "DB" and draw lines from the points on line "AC" to line "AB". Line "AB" will be divided into six equal parts.		
D. Constructing parallel lines.	II.D.1.Show Transparency 11CS-1551-115T-2, "Constructing Parallel Lines".	II.D.1.Draw figures following instruction in second section of paper.
1. Construction method.		
a. Given line AB and A perpendicular distance X to line OP to be constructed.		
b. Using C as A center on line AB, swing arcs D & E intersecting line AB.		
c. Using distance X as A radius and D and E as centers, swing arcs for line OP.		
d. Connect top of arcs for line of parallel to line AB.		
2. Transfer method.	II.D.2. Demonstrate on C/B.	
a. Set a straight edge and triangle combination so that triangle lies on given line.		
b. Slide triangle along straight edge to desired distance and draw parallel lines.	II.D.2.b. Have students remove sheet from board.	II.D.2.b. Remove sheet from board.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
E. Constructing Regular Polygons.		
1. Constructing a regular hexagon - across corners.	II.E. Show Transparency 11CS-1551-115T-3, "Constructing a Hexagon - Across Corners".	
a. Given line AE.	II.E.1: Instruct students to fasten third sheet to drawing board Divide paper into two (2) sections with pencil line.	II.E.1: Fasten third sheet to drawing board. Divide paper into two(2) sections with pencil line. Draw figures following instruction in first section.
b. Draw a circle with line AE as the diameter. Locate center and label it O.		
c. With the radius AO, and using A and E as centers, draw arcs intersecting the circle.		
d. Connect each intersection point with the next straight lines to form a regular hexagon.		
e. The same hexagon can be drawn with the use of a 30° - 60° triangle and a T-square.		
2. Constructing a Regular Hexagon across Flats.	II.E.2. Show Transparency 11CS-1551-115T-4, "Constructing a Regular Hexagon Across the Flats".	
a. Given distance "AE".		
b. Draw a circle with line "AE" as the diameter entering line "AE" beyond the circle on both sides.		II.E.2. Draw figure following instruction in the other section of the sheet.
c. Using a 30° - 60° triangle, draw 60 degree angles tangent to the circle as shown.	II.E.2.c. Have students remove sheet from board.	II.E.2.c. Remove sheet from board.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
F. Constructing an Octagon in a Square.	II.F. Show Transparency 11CS-1551-115T-5, "Constructing an Octagon in a Square".	
1. Draw a square and within the square draw diagonals to the corners.	II.F.1: Instruct students to fasten the fourth sheet to drawing board.	II.F.1: Fasten down fourth sheet to drawing board.
2. Using the corners of the square as centers and a radius equal to 1/2 of the diagonal, draw arcs intersecting the sides of the square.	Divide sheet into two (2) sections with pencil line.	Divide sheet into two (2) sections.
3. Connect these intersection points with lines which form the sides of the Octagon.		Draw figure following instruction in first section of the sheet.
G. Constructing a Regular Polygon with an Odd Number of Sides.	II.G. Show Transparency 11CS-1551-115T-6, "Constructing an Irregular Polygon".	
1. Given length of one side "AB". Extend out to left.		II.G.1. Draw figure following instructions in other section of sheet.
2. Construct a semi-circle using "AB" as the radius.		
3. Divide semi-circle into seven (7) sections by trial and error.		
4. Extend radius from "A" through the intersection points; using "AB" as radius swing arcs from points of intersection on the semi-circle from left skip the first two intersections then swing arcs.		
5. Connect the intersections of the long radius and the radius "AB" arcs with straight lines to form the polygon.	II.G.5. Have students remove sheet from drawing board.	II.G.5. Remove sheet from board.
	GIVE CLASS BREAK	LEAVE CLASSROOM.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT
H. Drawing a Given Tangent to a Given Line Passing Through a Given Point.	II.H. Show Transparency 11CS-1551-115T-7, "Circle Tangent to a Given Line Passing Through a Given Point".	
1. Give line "AB" and point "C" at a given distance from "AB".		II.H.1. Fasten fifth sheet to drawing board. Divide sheet into two (2) sections.
2. Through "C" construct a parallel line to "AB".	II.H.2. Instruct students to fasten fourth sheet to drawing board. Divide into two (2) sections with pencil line.	
3. Set the compass at "C" and using the distance from "C" to line "AB", swing an arc intersecting "DE" at point "K".		
4. Using "K" as the center and distance "KC" as a radius, construct circle through "C" and tangent to "AB".		Draw figure following instructions in first section.
I. Constructing an Ellipse Using the 4-Center Approximate Method.	II.1. Show Transparency 11CS-1551-115T-8, "Ellipse 4-Center Method".	
1. Given major axis "AB" and minor axis "DE", "O" at the center (perpendicular bisections each way).	II.I.1. Have students draw an ellipse using a 2" major axis and a 1½ " minor axis.	III.I.1. Draw figure following instructions in other section of sheet.
2. Connect points "A" and "D".		
3. Lay off "DF" equal to "AO" minus "DO" locates "F".		
4. Construct a perpendicular bisector of "AF" crossing "AO" at "G" and crossing "DE" at "H".		
5. Swing distance "OG" to fing "GI" and distance "OH" to find point "H".		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
6. Then "G", "GI","H", and "H1" will be centers for four tangent circle arcs forming a curve approximately the shape of an ellipse.		
J. Constructing Curves.	II.J. Show Transparency 11CS-1551-115T-9, "Reverse Curve Ogee".	
1. Ogee or reverse curve.		
a. Given two parallel lines "AB" and "DE".	II.J.1. Instruct student to fasten sixth sheet to drawing board.	II.J.1. Fasten sixth sheet to drawing board.
b. Connect "B" and "D" with a straight line (line "BD")		Draw figure following instruction.
c. Erect perpendicular from points "B" and "D".		
d. Establish point "F" at midpoint on "BD".		
e. Construct perpindicular bisectors to "FB" and "FD".		
f. Using the intersections of these bisectors and the perpindiculars from points "B" and "D" as centers swing in the arcs to form Ogee.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
III. Application		
A. Questions and Answers	III.A Questions	III.A Answers.
	1. What instruments are included in bow instruments?	1. Compass & dividers.
B. Practical Performance.		
1. Draw a figure using geometric construction procedures.	III.B.1. Pass out and explain Job Sheet SCBT 420.1 EA JS 1.2.3.1, "Geometric Construction". Guide students in application of constructing geometric figures.	III.B.1. Practice and work job sheet requirements.

IV. Summary

A. Compass and Bow Instruments.

B. Bisecting Lines and Angles.

C. Dividing a Line into any Number of Equal Parts.

D. Constructing Parallel Lines.

E. Constructing Regular Polygons.

F. Constructing An Octagon in a Square.

G. Constructing a Regular Polygon.

H. Drawing a Given Circle Tangent to a Given Line Passing Through a Given Point.

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

I. Constructing an Ellipse Using the Four-Center Approximate Method.

J. Constructing Curves.

V. Test:

A. Demonstrate ability to make good geometric figures using conventional drafting instruments.

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

JOB SHEET

TITLE: Geometric Construction

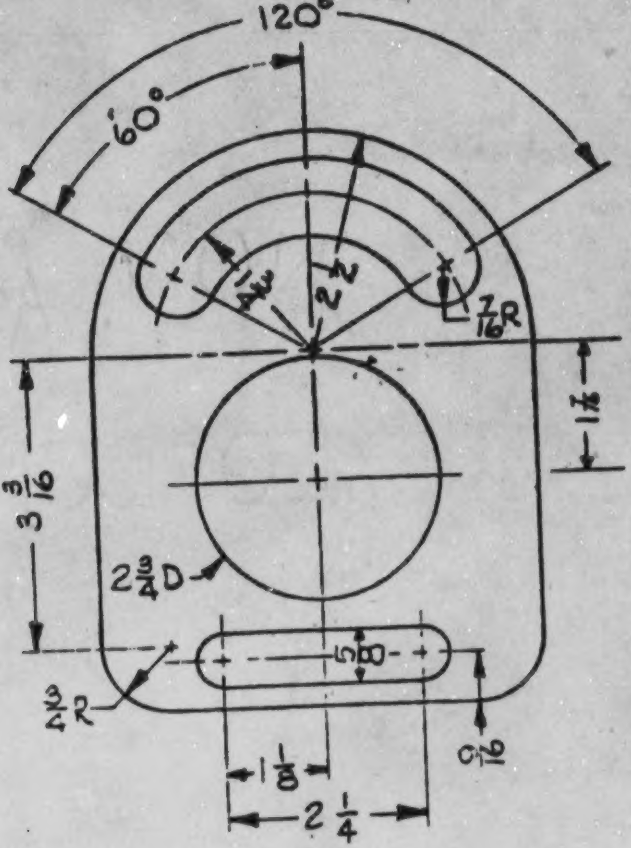
INTRODUCTION: The purpose of this job sheet is to guide you in the practical work assignment of drawing a meter cover. Your completed drawing will be used by the instructor to evaluate your ability to properly perform geometric constructions. After assembling the necessary tools and materials, read over the procedure rapidly, to get a general picture of the drawing requirements, then prepare the drawing insuring conformance to the requirements.

REFERENCES:

1. Engineering-Technical Drafting and Graphics, Chapter 4, pp. 56-82.
2. Military Standard, Engineering Drawing Practices, MIL-STD-100A, Pages 9 and 45.
3. Engineering Aid 3 & 2, pp. 101-121.

TOOLS, EQUIPMENT AND MATERIALS:

1. Pencils (as necessary)
2. Dusting brush.
3. Cleaning pad.
4. Architects scale.
5. Engineering scale.
6. Drafting set.
7. 30° - 60° triangle.
8. "A" size, tracing paper.
9. Drafting tape.
10. Eraser.
11. Erasing shield.
12. Drawing board/table.
13. T-square.



PROCEDURE: Draw the meter cover full scale on an "A" size sheet of tracing paper laid out in vertical format in accordance with MIL-STD-100A, Page 9. Layout procedures shall be in accordance with Engineering-Technical Drafting and Graphics, Chapter 4. Leave all your construction lines on your finished drawing. Place your last name in the lower right-hand margin in 5/32 inch high letters. Omit title block and revision block. Make a print of your finished drawing following Job Sheet 420.1 EA JS 1.2.8.1.

Completed drawing must meet acceptable standards of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1 for visible lines, line convenience, tangents, format, accuracy, and solution.

QUESTIONS: None

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

Classification: Unclassified

Topic: Orthographics

Average Time: 2 Periods (class) 5 Periods (Pract)

Instructional Material:

A. Texts:

1. Engineering-Technical Drafting & Graphics.
2. Engineering Aid 3 & 2. NAVPERS 10634.

B. References:

1. Architectural Drawing & Light Construction.
2. General Drafting.
3. Technical Drafting, Geske, Mitchell & Spencer

C. Tools, Equipment and Materials:

1. Equipment.
    - a. Compass.
    - b. Drawing board/table.
    - c. Scales.

Terminal Objective: Upon completion of this unit the student will be able to use the tools of a draftsman and perform the techniques and procedures related to basic drafting. All problem solutions submitted by the student as his finished product will meet the minimum requirements of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1.

Enabling Objectives: Upon completion of this topic the student will be able to construct two, three-view orthographic drawings of mechanical and construction objects following the fundamentals of orthographic projection and using standard drafting instruments. Text-books, other drafting publications or references as well as instructor guidance is encouraged in the completion of the requirements. Tracing of a completed orthographic drawing, other than that executed by the student, and the use of templates are not acceptable drawing procedures. All drawings submitted by the student as his finished assignment will meet the acceptable standards of SCBT 420.1 EA EG 1.2.0.1 for visible lines, line conventions, tangents, format accuracy and solution and of an opaque quality sufficient enough to make legible Diazo reproductions.

Criterion Test: The student will demonstrate his ability to draw orthographic drawings by completing the requirements of Job Sheet SCBT 420.1 EA JS 1.2.4.1. "Orthographic Projection".

(1) Architects.

(2) Civil Engineers.

d. 45° triangle.

e. T-square.

2. Materials.

a. Cleaning pad.

b. Drafting tape.

c. Eraser.

d. Erasing shield.

e. Pencils.

f. Tracing paper 11" x 17".

C. Training Aids and Devices:

1. Films:

a. MC-6797A - Engineering Drawing, Orthographic Projection. (18 min) Obsolete.

2. Slides (35 mm)

a. Orthographic Drawing, 091791, Part I, Set 4, McGraw-Hill.

b. Orthographic Drawing, 091794, Part II, Set 4, McGraw-Hill.

Homework: Read

Drafting and Graphics, Ch.5, pp. 89-103.

Engineering Aid 3 & 2, Ch. 5, pp. 122-137.

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3. Locally Prepared Materials:

   a. Job Sheet

      (1) SCBT 420.1 EA JS 1.2.4.1 "Orthographics".

D. Training Aids Equipment:

   1. Projectors.

      a. 16 mm Sound.

      b. 35 mm Slide.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name.		
2. Topic: Orthographics.		
B. Establish readiness.	I.B. Motivate student.	
1. Purpose.		
2. Assignment.		
C. Establish effect.	I.C. Bring out need and value of material being presented.	
1. Value.		
a. Pass course.		
b. Perform better on the job.		
c. Get advanced.		
d. Be a better Engineering Aid.		
D. Overview:	I.D. State learning objectives.	
1. Upon completion of this topic the student will be able to draw orthographic drawings to meet the acceptable standards of the Evaluation Guide SCBT 420.1 EA EG 1.2.0.1, for visible lines, line conventions, tangents, format, accuracy and solution.	I.D.1. State information and materials necessary to guide student.	

OUTLINE OF INSTRUCTION | INSTRUCTOR ACTIVITY | STUDENT ACTIVITY

II. Presentation.

A. Introduction

B. Purpose.

1. Presentatiion of three dimensional objects.

2. Describe the exact shape of objects.

C. Viewing the object.

1. Front view

2. Top view.

3. Right side view.

4. Standard practices - three views are used.

D. Theory of projection.

1. Imagine object in a plastic box.

2. Outlines of the object projected to the sides of the plastic box.

3. Open the plastic box.

a. Reveals how three views are established.

4. Top and front views with same width.
Side and front views drawn with same height.
Top and side views drawn with same depth.

II.A. Show film, MC-6797A, "Engineering Drawing, Orthographic Projection".

II.B. thru K. Show slides "or drawing".

OUTLINE OF INSTRUCTION | INSTRUCTOR ACTIVITY | STUDENT ACTIVITY

5. Other views available, left side, back, and bottom views.

E. Planes of projection.

1. Sides of transparent box are planes of projection.

2. Horizontal, frontal and profile planes.

3. Drawn in the true shape of the object.

4. Surfaces at right angles to planes of projection are seen as lines.

F. Hidden surface/features.

1. Hidden lines indicate hidden surface/features.

a. Hidden lines - short dashes approximately 1/8" long and spaced 1/16" apart.

G. Selection of the Main View - Front View.

1. Select view that tells the most about the object.

2. Other views fall into place from the front view.

H. Slanted Surfaces.

1. Shape may appear similar in two views.

2. Slanted surfaces appear foreshortened in some views.

3. One view must show true dimension of slanted surface.

I. Problems.

1. Complete the top view when given the front and right side view.

II.I.1. Complete the view on the C/B.

2. Draw the missing right-side view when given the front and top view.

II.I.2. Complete the view on the C/B.

J. Describing round objects.

1. Two views may become identical - eliminate one.

2. Holes shown as hidden lines in some views.

   a. Use center lines to indicate holes.

   b. Center lines are thin lines, long dashes with short dash cross at center of hole or arc.

3. Select the best view as front view, will show the most detail.

K. Holes, slots, cylinders and other surfaces are drawn in regular order.

L. Order of drawing.

1. Find the primary center of paper and locate base lines for the objects.

OUTLINE OF INSTRUCTION

2. Block in views, light construction lines.

3. Locate centers of circles/arcs in all views.

4. Draw circles/arcs.

5. Draw remaining figure.

III. Application.

A. Questions and Discussion.

INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
III.A. Questions.	III.A. Answers.
1. Name the planes of projection in orthographic projection.	1. Front, back, top, bottom, right, and left sides.
2. Hidden lines are used for showing what features?	2. Features that do not appear on a plane of projection as a line.
3. What plane is the rear plane attached to?	3. May be hinged to any plane except the front, generally the top.
4. How do you determine the number of views to use?	4. By the features of the object.
5. What lines on a drawing are secondary?	5. Hidden, and center lines.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
B. Practical Performance	III.B. Pass out and explain SCBT 420.1 EA JS 1.2.4.1, "Orthographic Projection". Guide students in application of orthographic drawings. Evaluate student performance on completed work	III.B. Practice and work job sheet requirements.
IV. Summary:		
A. Purpose of Orthographic Projection.		
B. Viewing the Object.		
C. Theory of Orthographic Projection.		
D. Planes of Projection.		
E. Hidden Surfaces/Features.		
F. Selection of the Front View.		
G. Slanted Surfaces.		
H. Describing Round Objects.		
I. Order of Drawing.		
V. Test.		
A. Demonstrate ability to make good orthographic drawings using conventional drafting equipment.		

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PORT HUENEME, CALIFORNIA 93043
SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

JOB SHEET

TITLE: ORTHOGRAPHIC PROJECTION

INTRODUCTION: The principal task in learning orthographic projection is to become thoroughly familiar with the theory and then to practice this theory by translating from a picture of an object to the orthographic views. This job sheet will assist you in properly completing the practical assignment of preparing orthographic projections. After assembling the necessary tools and materials, read through the procedures rapidly to get a general picture of the requirements, then prepare the assigned orthographic drawings.

REFERENCES:

1. Military Standard, Engineering Drawing Practice, MIL-STD-100A, Pages 9 and 45.
2. Engineering-Technical Drafting and Graphics, Chapter 5, pp. 89-103.
3. Engineering Aid 3 & 2, NAVPERS 10634-B, pp. 122-123.

TOOLS, EQUIPMENT AND MATERIALS:

1. Sketch pad.
2. Engineers scale.
3. Architects scale.
4. Compass.
5. Pencils (as necessary).
6. Erasing shield.
7. Cleaning pad.
8. 45 degree triangle.
9. Two (2) "B" size tracing sheets.
10. T-square.
11. Drawing board/table.
12. Drafting tape.

PROCEDURES:

Part 1: Prepare layout sketches of both problems referred to on this job sheet. These sketches will meet the requirements of topic 2.1.5 of Basic Drafting and be approved by the instructor prior to starting Problem 1 and 2.

Part 2: Draw each problem on a "B" size sheet of tracing paper with standard borders in accordance with MIL-STD 100A, Page 9, omit title block and revision block. Leave all construction lines on finished drawings. Label all views with 3/16" high letters. Place your last name in the lower right-margin in 5/32" high letters. Make a print of each drawing following procedures of Job Sheet SCBT 420.1 EA JS 1.2.8.1.

Part 3: Completed work must meet the acceptable standards of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1 for visible lines, line convention, tangents, format, accuracy and solution.

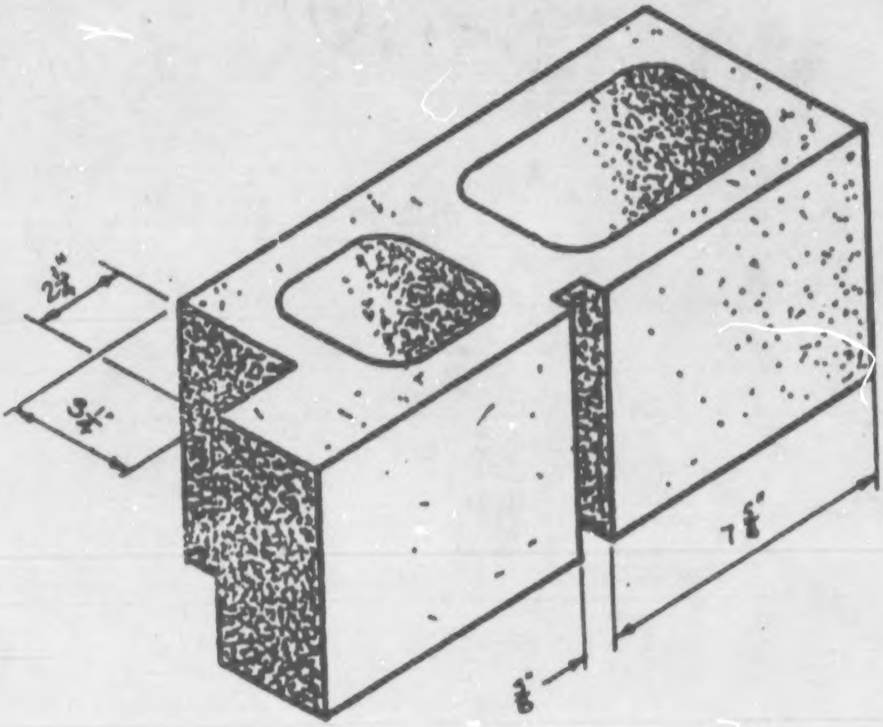
PROBLEM #1

Draw a 3 view orthographic drawing showing the "Special center-scored jamb-corner" masonry unit, scale 3" - 10".

PROBLEM #2

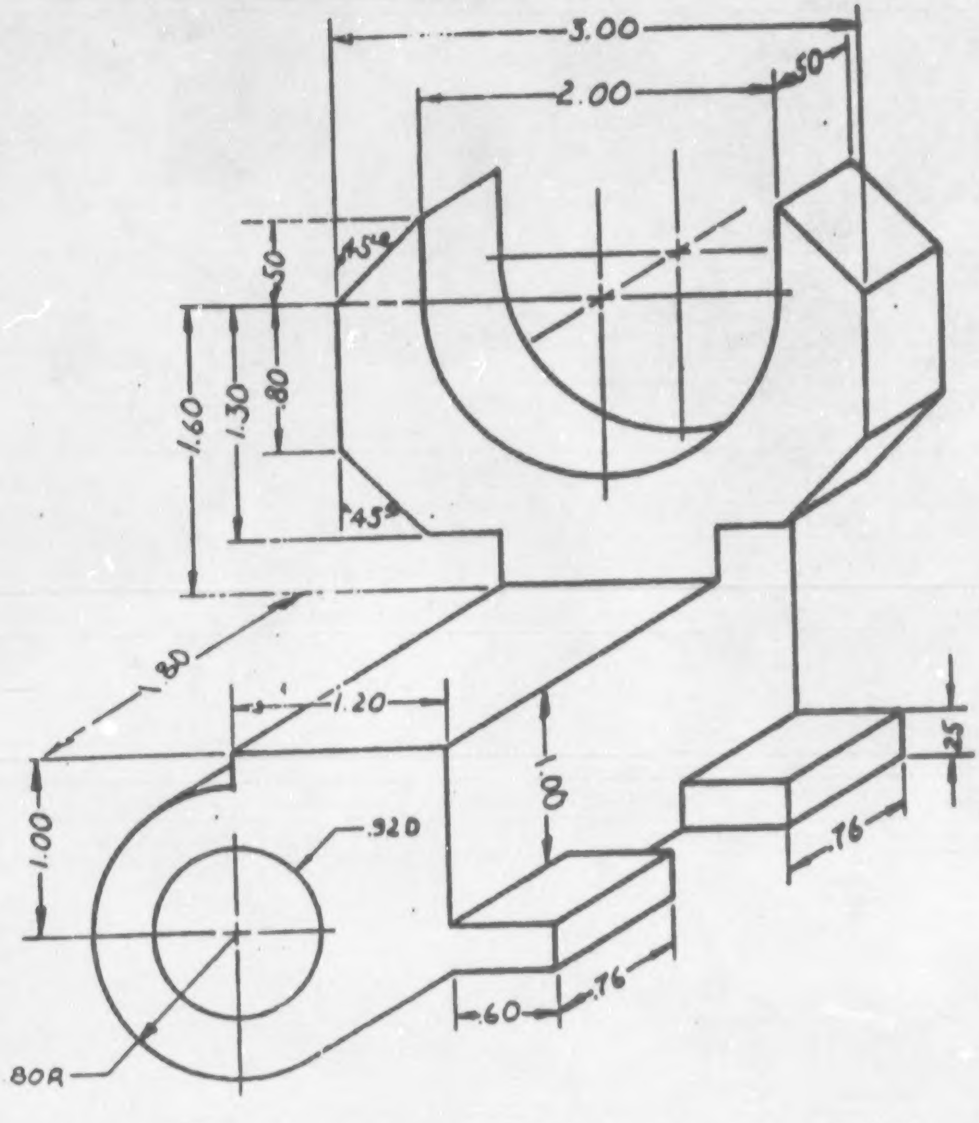
Draw a full scale 3 view orthographic drawing of the "Reversing Fork".

QUESTIONS: None



SPECIAL CENTER-SCORED JAMB-CORNER HEAVYWEIGHT CONCRETE MASONRY UNIT

ACTUAL SIZE: 7 5/8" X 7 5/8" X 15 5/8"
NOMINAL SIZE: 8 x 8 x 16
WEB THICKNESS: 1 1/4"
DEPTH OF SCORE: 3/8"
RADII: 1"


3.00
2.00
.50
.50
45°
1.60
1.30
.80
45°
1.80
1.20
1.00
.92D
1.00
.25
.76
.76
.60
.80R

REVERSING FORK

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

Classification: Unclassified

Topic: Sections and Dimensions

Average Time: 3 Periods (Class) 6 Periods (Pract)

Instructional Materials:

A. Texts:

1. Engineering-Technical Drafting & Graphics, Chapters 6 and 8.

B. References:

1. Architectural Drawing & Light Construction, pp. 48-54 and pp. 189-195.
2. General Drafting, TM5-230, pp. 77-81 and pp. 87-95.

C. Tools, Equipment and Materials:

1. Drawing board/table.
2. Architects scale.
3. T-square.

Terminal Objective: Upon completion of this unit the student will be able to use the tools of a draftsman and perform the techniques and procedures related to basic drafting. All problem solutions submitted by the student as his finished product will meet the minimum requirements of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1.

Enabling Objectives: Upon completion of this topic the student will be able to construct three sectional views of mechanical and construction objects with dimensions and notes as specified for mechanical and construction drawings and using standard drafting instruments. Tracing of a completed drawing other than one executed by the student and the use of templates are not acceptable drawing procedures. The drawing submitted by the student as his finished assignment will meet the acceptable standards of SCBT 420.1 EA EG 1.2.0.1, for all 10 parts of a drawing and of an opaque quality sufficient enough to make a legible Diazo reproduction.

Criterion Test: The student will demonstrate his ability to draw sections by accomplishing the requirements of SCBT 420.1 EA JS 1.2.5.1, "Sections and Dimensions".

Homework: Read

Engineering-Technical Drafting & Graphics, pp. 110-132 and pp. 187-201.

4. 45° triangle.

5. Compass.

6. Tracing paper, 11" x 17".

7. Drafting tape.

8. Dividers.

9. Pencils.

10. Erasing shield.

D. Training Aids and Devices:

1. Films:

   a. MC-6794-A "Engineering Drawing-Sections and Conventions" (15 min.)

   b. MC-6796-A "Engineering Drawing, Selection of Dimensions" (18 min.)

   c. 091792 - "Dimensioning", Part I, Set 4, McGraw-Hill Book Co.

   d. 091795 - "Dimensioning", Part II, Set 4, McGraw-Hill Book Co.

   e. 091796 - "Sectional Views", Set 4, McGraw-Hill Book Co. New York, N.Y.

2. Locally Prepared Material:

   a. Job Sheet.

      (1) SCBT 420.1 EA JS 1.2.5.1, Sections and Dimensions".

E. Training Aids Equipment:

1. Projectors.

a. 16 mm Sound.

b. 35 mm Slide.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name.		
2. Topic: Sections and Dimensions.		
B. Establish readiness.	I.B. Motivate student	
1. Purpose.		
2. Assignment.		
C. Establish effect.	I.C. Bring out need and value of materials being presented.	
1. Value.		
a. Pass course.		
b. Perform better on the job.		
c. Get advanced.		
d. Be a better Engineering Aid.		
D. Overview.	I.D. State learning objecives.	
1. You will be able to construct sectional views of mechanical and constructional items.	I.D.1. State information and materials necessary to guide student.	
2. Ask questions.		
3. Take notes.		
4. Textable.		

II. Presentation.

A. Dimensions.

1. Definition.

a. Text - A dimension is a numerical value expressed in appropriate units of measure. It is indicated on drawings in conjunction with lines, symbols and notes to define the geometrical characteristics of an object.

2. Requirements.

a. Interpretation.

(1) There shall be only one interpretation.

(2) May deviate from rules only if clarity improved.

b. Adequacy.

(1) Dimensions must be complete without repetition.

(2) Dimension to surface, line or point.

(a) By one set of dimensions only.

(b) Dimensions shall not be duplicated in other views unless clarity can be improved.

3. Systems.

a. Two basic systems used.

(1) Aligned.

(a) All dimensions and their corresponding numbers are so spaced so that they may be read from the bottom or from the right-hand edge of the drawing.

(b) Numbers, guide lines parallel to dimension line.

(2) Unidirectional.

(a) All dimensions are made to read from the bottom of the drawing.

(3) Aligned is preferred and will be used in this course.

(4) Dimensions up to and including 72" may be expressed in inches.

(a) Over 72 inches, expressed in feet and inches.

1. Example: 8' - 7".

B. Dimensioning Conventions.

1. Dimensions - Applications:

a. Extension lines.

(1) Thin lines.

(2) Shall start 1/16" from object line.

(3) Shall terminate 1/8" beyond dimension line.

b. Dimension lines.

(1) Thin line.

(2) First line 3/8" from object lines.

(3) To be minimum of 1/4" apart.

(4) Dimension lines in architectural are solid.

(a) Figures above lines.

(5) Machine, lines will be broken for figures.

c. Arrowheads.

(1) Shall be small, solid, no hooks.

(2) The point shall be as thick as line.

(3) Should be 1/3 as wide as length.

(4) No other type of arrow will be accepted.

d. Center lines as dimension lines.

(1) Usually end 1/8" beyond object line.

(2) Same rules apply as extension lines when used as such.

e. Leader lines.

(1) Architectural

  (a) Freehand and thin.

(2) Machine

  (a) Mechanical and thin.

(3) Leaders shall terminate on surface point or edge with arrow.

  (a) Leaders shall start in center of start or finish of note.

(4) Leaders look better if drawn parallel to each other.

  (a) NEVER parallel to lines of drawing.

  (b) Approximately 60° is recommended.

2. Rules for dimensioning.

a. Color

(1) The use of colored pencils for dimensions does not adversely affect an original's reproduction quality.

(2) Colors

  (a) Red - Makes original easy to read.

    1 Contrast between black and red.

(b) Blue - Some blues will not reproduce. Good for writing information on originals for office use only.

b. Placing dimensions

(1) Shorter dimensions nearer object.

(2) Center between arrowheads (numerals).

c. Dimensioning holes and arcs.

(1) All holes and arcs shall be dimensioned by leaders.

(2) Leaders for holes.

(a) Holes 5/8" or larger.

1 Extend across holes.

(b) Smaller than 5/8".

1 To surface of circle, centered between center lines.

(3) Holes and arcs dimensioned on view they appear.

(4) Always locate holes by center lines.

(a) On view they appear.

(5) Fillets and rounds.

(a) By radius.

(b) Refer to MIL Standards.

d. Chamfers

(1) Two ways.

(2) When space limited.

(a) By note.

(b) Refer to MIL-STD.

(3) When space permits.

(a) By note.

(b) Extension lines and angles.

e. Wood - Center-to-Center or Face-to-Face.

(1) Openings to center.

(2) Corner post - face or post not face of exterior siding.

f. Concrete. Face-to-face.

(1) Openings - face-to-face

(2) Wall thickness must be given.

g. Steel. Center-to-center or face-to-face

(1) Openings - face across.

(2) Member size dimension given by note.

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

h. Sectioning - Show typical section with required dimensions. This should also include details.

i. Other rules.

(1) These rules must be followed unless clarity improved.

(2) Questions not answered by these rules will be answered in MIL-STD-8C.

(a) Dimension off view.

(b) Dimension off cut surface of section views.

1 Omit section lines around numerals when necessary to dimension on surface.

(c) Between views.

(d) One view only.

(e) Mid-way between arrowheads.

(f) All notes must be read horizontally.

(g) Never use extension lines, centerlines or object lines as dimension lines.

(h) Never cross dimension lines with extension lines.

1 If must cross, break extension lines.

(i) Avoid dimensioning to hidden lines.

(j) Extension lines do not break crossing object lines.

C. Importance of Sections.

1. Clarity of construction materials.

a. Hidden lines to show features.

(1) Result hodgepodge of lines.

2. What is a section.

a. Imaginary cut or plane.

(1) Material in front removed.

b. Result is line and x-ray, allows people to see interior details.

D. Conventions. Used in sectioning.

1. Cutting plane.

a. Imaginary cut or plane.

b. Indicated on a drawing by:

(1) Arrows with letters 1/4" high.

(2) Circles, squares or etc. with numerals and letters which give:

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(a) Section

(b) Number

(c) Sheet on which section is drawn.

2. Outline of solid objects.

a. Object or visible lines.

b. Shows outlines of materials and voids in betweeen.

3. Hidden features.

a. Sections are drawn to get away from this problem therefore, omit them on drawing.

b. Only for clarity.

4. Holes, ribs, and spokes.

a. Revolved into cutting plane.

b. Shown on section for true representation.

5. Bolts, screws, shafts, rods, rivets, and objects of this type.

a. Draw as if viewed from outside, not sectioned.

6. Cross-hatching

a. Section lines shall be composed of uniformly spaced lines drawn at 45° to the base line.

(1) Adjacent parts shall have section lines drawn in the opposite direction.

(2) When third part drawn, section lines drawn at 30° to 60°.

7. Lettering on sections.

a. Omit section lines in this area.

8. Section titles

a. Cutting plane indication letters always appear with the title.

b. Section 5/32" high.

c. Letters 1/4" high.

E. Types of Sections

1. Full section

a. A view obtained when cutting plane extends across the entire object.

2. Half section

a. A view of a symmetrical object which shows the internal and external features.

b. This is accomplished by passing two cutting planes at right angles to each other along center lines of symmetrical axis, thus one quarter of the object is considered removed and interior exposed to view.

c. Cutting plane lines and section titles are omitted.

3. Broken out sections.

a. When a section of only part of an object is needed.

b. The appropriate break lines are used.

(1) To separate the section from the exterior view.

4. Revolved sections.

a. The cutting plane is passed perpendicular to the center line or axis of the part to be sectioned and the resulting section is rotated in place and drawn on view.

5. Revolved partial section.

a. Used to show only part of an object.

(1) Face configuration

6. Removed section

a. Used to illustrate particular parts of an object.

b. Drawn as revolved sections but drawn to one side.

c. Usually drawn to larger scale.

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

7. Pictorial section
   - a. Used because of simplicity in reading.
   - b. In pictorial work show both external and internal features on one drawing.
   - c. Full, half and broken-out sections most common.
8. Thin sections
   - a. Used to represent planes, gaskets, and other parts.
     - (1) Scale too small to draw a conventional section.
9. Offset section
   - a. When the cutting plane must follow an irregular path thru an object.
     - (1) This is done to include features that otherwise would be omitted.
10. Aligned sections
    - a. When the true projection of a piece may be misleading.
      - (1) Such as ribs, spokes or similar elements.
    - b. Draw as if rotated in or out of the cutting plane.

OUTLINE OF INSTRUCTION

III. APPLICATION

A. Questions and Discussion

INSTRUCTOR ACTIVITY | **STUDENT ACTIVITY**

QUESTIONS:	**ANSWERS:**
a. What dimensional system is preferred by the military?	a. Aligned
b. What are the rules for drawing dimension lines?	b. Thin, first 3/8" from object, 1/4 to next line.
c. On what type of drawing are dimension lines broken?	c. Machine
d. Where do the arrowheads on leaders terminate?	d. Surface point or edge.
e. When is it permissible to draw the leader across a hole for dimensioning?	e. When the hole is 5/8" or larger.
f. How are fillets and rounds dimensioned?	f. By radius.
g. If you must cross dimension and extension lines which line should you break?	g. Extension lines.
h. When is it permissible to deviate from the rules for dimensioning?	h. For clarity.
i. What is a sectional view?	i. Inside view of object.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
	j. When should a sectional view be drawn?	j. Hidden features not shown in other views.
	k. Describe a half-section.	k. Two cut planes at right angles on axis of summetrical object, 1/4 object removed.
	l. When is a revolved section removed?	l. When drawn to large scale and for clarity.
	m. Where are reference letters used in conjunction with cutting plane?	m. Changes of direction.
B. Practical Application	III.B. Pass out and Explain SCBT 420.1 EA JS 1.2.5.1 Guide Students in application.	III.B. Work on job sheet requirements under instructor guidance.
IV. SUMMARY:		
A. Dimensions		
1. Definition		
2. Types		
3. Systems		
4. Requirements		
B. Dimensioning Conventions		
1. Application		
2. Rules for		

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

C. Importance of Sections

D. Sectioning Conventions

   1. Cutting plane
   2. Outlines
   3. Hidden features
   4. Holes, ribs, and spokes
   5. Bolts, screws, shafts, rods, rivets, and etc.
   6. Crosshatching
   7. Lettering on sections
   8. Section titles

E. Types of Sections

   1. Full section
   2. Half
   3. Broken out
   4. Revolved
   5. Partial revolved
   6. Removed
   7. Pictorial
   8. Thin

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY

9. Offset
10. Aligned

V. TEST

A. Job Sheet Completion

1. Students must satisfactorily complete job sheet requirements prior to start of next work day.

NAVAL CONSTRUCTION TRAINING CENTER
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SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

JOB SHEET

TITLE: SECTIONING AND DIMENSIONING

INTRODUCTION: The purpose of this job sheet is to guide you in the practical work assignment in sectioning and dimensioning. After assembling the necessary tools and materials, read over the procedures rapidly to get a general picture of the drawing requirements, then complete each of the assigned plates.

REFERENCES:

1. Engineering-Technical Drafting and Graphics, pp. 110-136 and 187-204.
2. Architectural Drawing and Light Construction, pp. 48-52 and 191-195.

TOOLS, EQUIPMENT AND MATERIALS:

1. Drawing board/table.
2. Three sheets "B" size tracing paper.
3. Drafting tape.
4. Architects scale.
5. Dividers.
6. Pencils (as necessary).
7. T-square.
8. Erasing shield.
9. Triangles.
10. Compass.

PROCEDURES: On an "A" size sheet sketch out the solution to the drawing problem for instructor approval before proceeding to do the final drawing, sketch will meet the minimum requirements of Topic 1.2.2 "Basic Sketching".

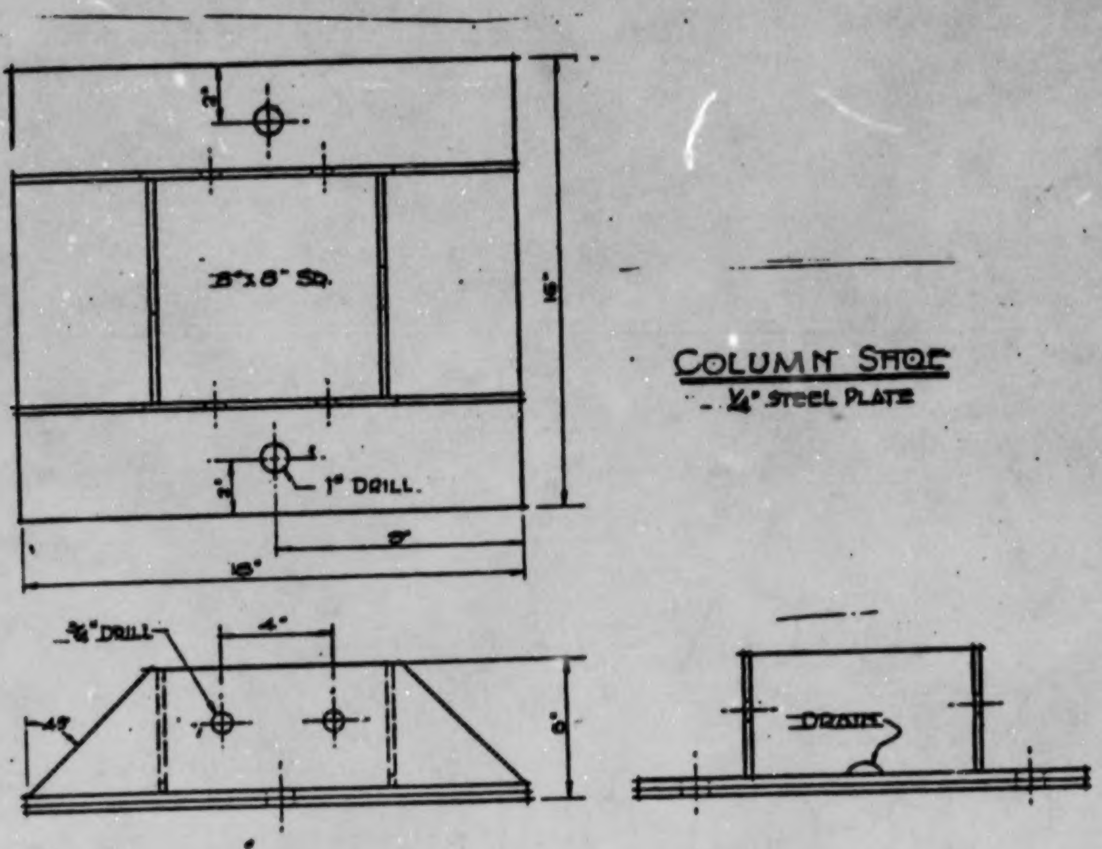
Draw each drawing on a "B" size sheet of tracing paper, complete with proper border as noted in MIL-STD-100A, Page 9. Omit the title and revision blocks. Include all mechanical dimensions, properly applied, necessary for proper fabrication. Leave all light construction lines on finished drawings. Place your last name in the lower right margin in 5/32" high letters.

Make a print of each drawing following the procedure set forth in SCBT 420.1 EA JS 1.2.8.1. Completed work must meet the acceptable standards of SCBT 420.1 EA EG 1.2.0.1 for visible lines, dimensions, line conventions tangents, format, lettering numerals and fractions, accuracy and solution.

QUESTIONS: None

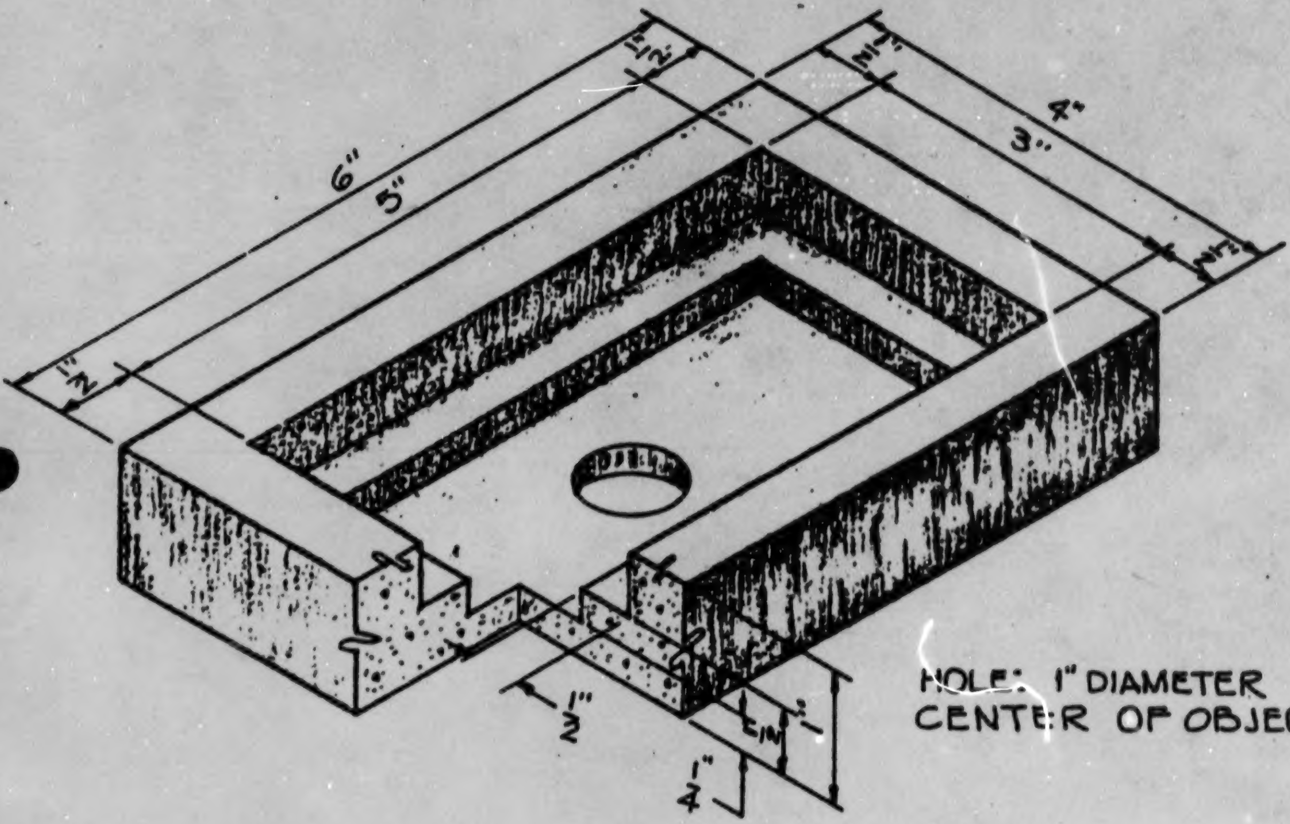
PROBLEM 1.

Redraw the top view of the following object to 1/4 scale (3"-1'-0"). Draw the front view in section. Note the material and use proper symbols.


2"
8"x8" SQ.
16"
1" DRILL.
2"
8"
16"
COLUMN SHOE
1/4" STEEL PLATE
3/4" DRILL
4"
45°
6"
DRAIN

PROBLEM 2.

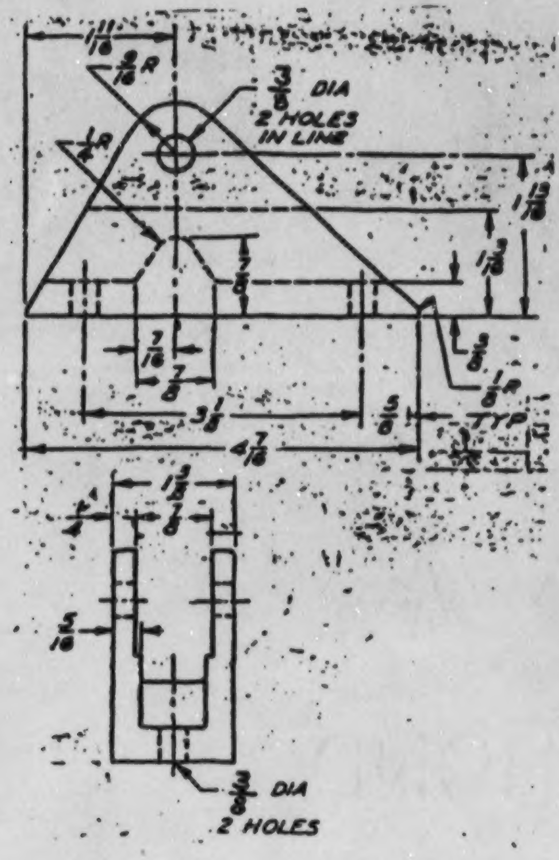
Cover Plate: Reproduce the front view and draw the top view as a full section. Material, concrete. Views are to be drawn full scale and using mechanical dimensioning.



HOLE: 1" DIAMETER
CENTER OF OBJECT

Problem 3.

Redraw the two views shown plus a third view in full section of the object below to full scale, note the material, use of proper symbols, and use mechanical dimensioning.


1 11/16
9/16 R
3/8 DIA
2 HOLES
IN LINE
1/4 R
1 13/16
1 3/16
7/8
3/8
1/8 R
TYP
7/16
7/8
3 1/8
5/8
4 7/16
1 3/8
1/4
7/8
5/16
3/8 DIA
2 HOLES

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

Classification: Unclassified.

Topic: Auxiliary Projection.

Average Time: 2 Period (Class) 7 Periods (Pract).

Instructional Materials:

A. Texts.

1. Engineering Aid 3 & 2, NAVPERS 10634-B
2. Engineering Technical Drafting & Graphics, 2nd Edition.

B. References:

1. Architectural Drawing & Light Construction
2. General Drafting, TM5-230.

C. Tools, Equipment and Materials:

1. T-square.
2. Drawing table.
3. Architects scale.
4. Compass.
5. 45 degree triangle.

Terminal Objective: Upon completion of this unit the student will be able to use the tools of a draftsman and perform the techniques and procedures related to basic drafting. All problem solutions submitted by the student as his finished product will meet the minimum requirements of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1.

Enabling Objectives; Upon completion of this topic the student will be able to construct a two-view orthographic drawing of a structure with an accompanying auxiliary view following the fundamentals of orthographic and auxiliary projection while using standard drafting instruments. The figures of the drawing are to be annotated with dimensions and notes as specified for construction drawings. Individual instructor guidance, textbooks and other drafting publications may be utilized in the performance of this topic. Tracing of a completed drawing other than one executed by the student, and the use of templates are not acceptable drawing procedures. The drawing submitted by the student as his finished assignment will meet the acceptable standards of SCBT 420.1 EA EG 1.2.0.1, for visible lines, notes, line conventions, tangents, format, lettering, numerals and fractions, accuracy and solution and be of an opaque-quality sufficient enough to make a legible Diazo reproduction.

Criterion Test: The student will demonstrate his ability to draw an auxiliary view by completing the requirements of SCBT 420.1 EA JS 1.2.6.1 "Auxiliary Projection".

6. Tracing paper.

7. Drafting tape.

8. Drawing pencils.

9. Eraser.

10. Erasing shield.

D. Training Aids and Devices:

1. Films.

   a. MC-6792A "Engineering Drawing-Auxiliary Views", (23 min.)

2. Slides.

   a. 091793, Set 4, "Auxiliary Views and Related Construction, McGraw-Hill, New York, N.Y.

3. Locally Prepared Material.

   1. Job Sheet.

      a. SCBT 420.1 EA JS 1.2.6.1, "Auxiliary Projections".

E. Training Aids Equipment.

1. Projectors.

   a. 16 mm Motion Picture.

   b. 35 mm Slide.

Homework: Read

Engineering Aid 3 & 2, pp. 138-140.

Drafting and Graphics. Ch. 9, pp. 207-210.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name.		
2. Topic: Auxiliary Projection.		
B. Establish readiness.	I.B. Motivate student	
1. Purpose: Further ability in drafting.		
2. Assignment: One "B" size drawing.		
C. Establish affect.	I.C. Bring out need & value of material being presented.	
1. Value.		
a. Pass course.		
b. Perform better on the job.		
c. Get advanced.		
d. Be a better Engineering Aid.		
D. Overview:	I.D. State learning objectives.	
1. You will be able to draw auxiliary views using necessary views of an orthographic projection - drawing will meet standards of evaluations as noted in evaluation guide.	I.D.1. State information and materials necessary to guide student.	
2. Ask questions.		
3. Take notes.		
4. Testable.		

OUTLINE OF INSTRUCTION

II. Presentation:

A. Introduction

B. Why Auxiliaries Are Used.

1. To find the true shape of an inclined surface not perpendicular to one of the major views.

2. Auxiliary views are accomplished by:

   a. (Using the transparent box concept) set a projection plane parallel to the slant surface.

   b. The outline of the slant surface will project to the projection plane in its true shape - called the auxiliary plane.

C. Constructing Auxiliary Views

1. In many cases an auxiliary view takes the place of one of the major views.

2. Draw a line parallel, at a convenient distance, to the slant surface.

3. From this view, project the extremities of the auxiliary view.

4. From the other view, determine the other dimension of the auxiliary.

5. Darken in view.

6. May be drawn off any of the regular views in which a slant surface appears as an edge.

INSTRUCTOR ACTIVITY

II.A. Show film - "Engineering Drawing-Auxiliary Views", MC-6792A.

II.B. Slides - "Auxiliary Views" - Outline of instruction follows the slide presentation, 091793.

STUDENT ACTIVITY

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
7. Problem	II.C.7. Construct a problem on chalkboard given two views, and make auxiliary.	II.C.7. Students respond in establishing solution to the problem.
D. Auxiliary Views Involving Circles		
1. Locate points outlining the circle view.		
2. Drop cords over curved surface.		
3. Project cords to other view.		
4. Project cords out perpendicular at point of contact on the slant surface.		
5. Establish a centerline for the auxiliary - at a sufficient distance away and parallel to slant surface.		
6. Transfer cord lengths (center line to outside of circle) from circle view to auxiliary - located by following lines of projection - set off lengths from established center line of auxiliary.		
7. Darken in view		
E. For Auxiliaries of Surfaces Which Are Not Shown In True Length On Any Of The Principal Views		
1. Establish an auxiliary center line parallel to the slant surface - distance greater than any measurement of the object.		
2. Project extremities of slanted surface.		
3. Transfer other dimension from other view to auxiliary (1/2 on each side of center line).		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
4. Establish all corners and features.		
5. Darken in view.		
F. Auxiliary Views for Unsymmetrical Objects		
1. Establish a reference plane for the object.		
2. Construct reference plane line parallel to slanted surface at a sufficient distance to allow for view.		
3. Transfer measurements and measure from reference plane line in auxiliary.		
4. Darken in view.		
G. Other Uses of Auxiliary Views		
1. Partial auxiliary view		
a. To completely describe an object with a minimum of drawing.		
2. Auxiliary sections		
a. To clarify interior details.		
III. Application:		
A. Questions and Discussion	III.A. Questions	III.A. Answers
	1. Define an auxiliary projection.	1. An orthographic projection on a plane which is not one of the principal planes of projection.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
	2. What is the purpose of auxiliary views?	2. To show inclined surfaces, features, and important dimensions.
	3. How many orthographic views should you draw for constructing an auxiliary view?	3. Generally, two
	4. In what type of auxiliary is it necessary to use many points of projection?	4. Auxiliary involving a circle.
	5. How would details of the interior of an object with a slant surface be shown?	5. By using an auxiliary section.
B. Practical Performance	III.B. Pass out and explain SCBT 420.1 EA.JS.1.2.6.1 "Auxiliary Projection". Guide students in application of making auxiliary views. Evaluate student performance on completed work.	III.B. Practice and work job sheet requirements.

IV. Summary:

A. Why Auxiliaries Are Used.

B. Constructing Auxiliary Views.

C. Auxiliary Views Involving Circles

D. Auxiliary Surfaces Which Do Not Show The True Length In Any Principal View

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
E. Auxiliary Views for Unsymmetrical Objects		
F. Other Uses Of Auxiliary Views		
V. Test:		
A. Demonstrate ability to make good auxiliary views using conventional drafting equipment.		

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SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

JOB SHEET

TITLE: Auxiliary Projection.

INTRODUCTION: The purpose of this job sheet is to assist you in the proper completion of your practical assignment in auxiliary projection. After assembling the necessary tools, equipment and materials, read over the procedures rapidly to get a general picture of the drawing requirements, then prepare the drawing, insuring compliance with the requirements.

REFERENCES:

1. Military Standards, Engineering Drawing Practices, MIL-STD-100A, Pages 9 and 45.
2. Engineering-Technical Drafting and Graphics, Chapter 9, pp. 207-212.
3. Dimensioning and Tolerancing for Engineering Drawings, USASI Y14.5 - 1966, American Society of Mechanical Engineers, Chapter 1.
4. Engineering Aid 3 & 2, pp. 138-139.

TOOLS, EQUIPMENT AND MATERIALS:

Equipment.

1. T-square.
2. Drawing board/table.
3. Architects scale.
4. Compass.
5. 45 degree triangle.

Material.

6. Tracing paper, 1 sheet size "C".
7. Drafting tape.
8. Pencils.
9. Eraser.
10. Erasing shield.

PROCEDURES: On a "A" size sheet, sketch out the solution to the drawing problem for instructor approval before proceeding to do the final drawing. All sketches will meet the minimum requirements of Topic 1.2.8"Basic Sketching".

On a "B" size sheet of tracing paper, with standard borders in accordance with MIL-STD-100A, Page 9, omit title block; draw two principal views and a partial auxiliary view. Layout procedures should be in accordance with "Engineering-Technical Drafting and Graphics", Chapter 9. Include all mechanical dimensions, properly applied in accordance with USASI Y14.5 - . 1966, Chapter 1.

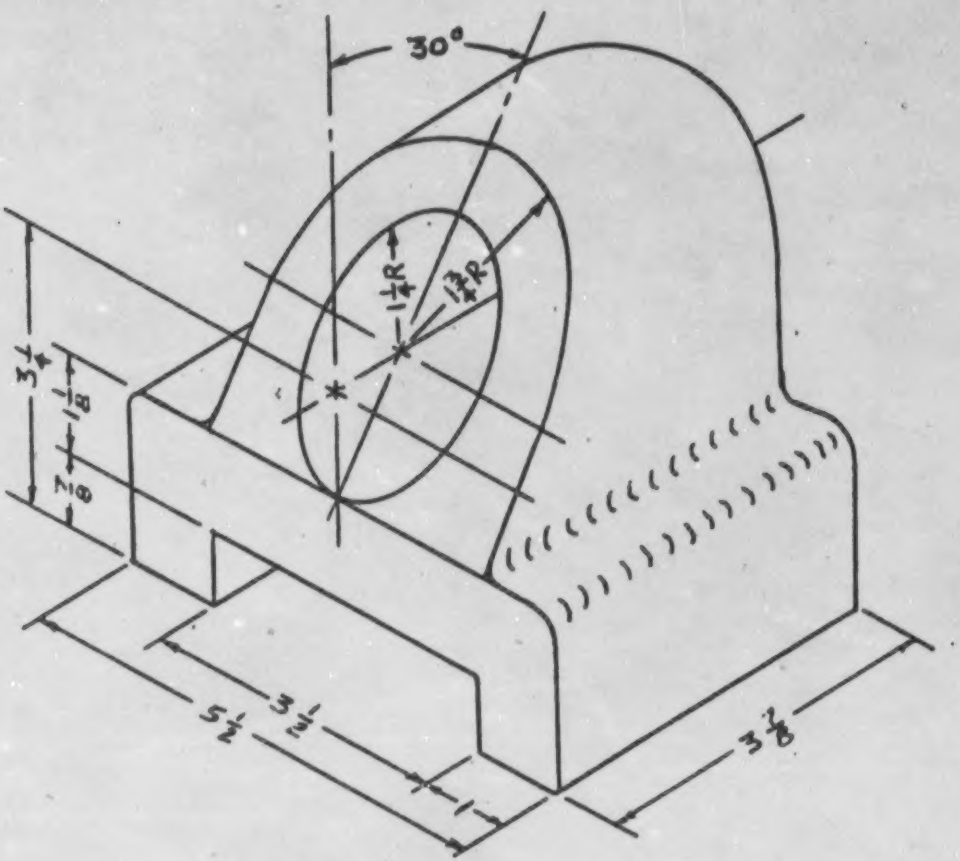
Place last name in lower right margin in 5/32" high letters. Make a print of your finished drawing following SCBT 420.1 EA JS 1.2.6.1.

Label all sub titles with 3/16" letters.

Completed drawings must meet the acceptable standards of evaluation guide EA EG 1.2.0.1.

A. Make a dimensioned drawing of the rod guide of the sketch on this page showing the necessary principal and auxiliary views. Use mechanical dimensioning as shown.

ROD GUIDE


30°
$1\frac{1}{4}$R
$1\frac{3}{4}$R
$3\frac{1}{4}$
$1\frac{1}{8}$
$\frac{7}{8}$
$5\frac{1}{2}$
$3\frac{1}{2}$
1
$3\frac{7}{8}$

HOLE THRU STOCK

ALL ROUNDS AND FILLETS 1/4 R

NAVAL CONSTRUCTION TRAINING CENTER
PORT HUENEME, CALIFORNIA 93043
SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

Classification: Unclassified

Topic: Isometric and Oblique Drawings

Average Time: 3 Periods (Class) 6 Periods (Pract)

Instructional Materials:

A. Texts:

1. Engineering Aid 3 & 2, NAVPERS 10634-B
2. Engineering-Technical Drafting & Graphics, 2nd Edition.

B. References:

1. Architectural Drawing & Light Construction
2. Blueprint Reading & Sketching, NAVPERS 10077-C
3. General Drafting, TM5-230

C. Tools, Equipment and Materials:

1. Equipment.
    - a. Architects scale.
    - b. Bench brush.
    - c. Compass.

Terminal Objective: Upon completion of this unit the student will be able to use the tools of a draftsman and perform the techniques and procedures related to basic drafting. All problem solutions submitted by the student as his finished product will meet the minimum requirements of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1

Enabling Objectives: Upon completion of this topic the student will be able to construct one isometric drawing, one oblique cavalier drawing of a mechanical and two construction objects following the fundamentals of isometric and oblique projection and using standard drafting instruments. The drawings will be annotated with dimensions and notes as specified for mechanical and construction drawings. Examples of various isometric and oblique drawings found in reference material and textbooks and the guidance of the instructor are encouraged in the performance of the requirements of this topic. Tracing of a completed drawing, other than one executed by the student, and the use of the templates are not acceptable drawing procedures. The drawings submitted by the student as his finished assignment will meet the acceptable standards of SCBT 420.1 EA EG 1.2.0.1 for visible lines, notes, line conventions, tangents, format, lettering, numerals, and fractions, accuracy and solution, and be of an opaque quality sufficient enough to make a legible Diazo reproduction.

Criterion Test: The student will demonstrate his ability to draw isometric and oblique drawings by satisfactorily completing the requirements of SCBT 420.1 EA JS 1.2.7.1 "Isometric and Oblique Drawings".

- (1) Bow
- (2) Pivot

d. Triangles.

- (1) 30° - 60°
- (2) 45°

2. Materials.

- a. Drafting tape.
- b. Dry-clean pad.
- c. Pencils.
- d. Tracing paper, 8½ x 11".
- e. Diazo print paper, 8½ x 11"

D. Training Aids and Devices:

1. Slides, 35 mm.

a. Isometric Drawing, 65623 Set 3
McGraw-Hill Book Co. New York, N.Y.

2. Locally Prepared Material:

a. Job Sheet

(1) SCBT 420.1 EA JS 1.2.7.1
"Isometric and Oblique Drawings".

Homework: Read

Drafting and Graphics, Chapter 15, pp. 443-456.

Engineering Aid 3 & 2, NAVPERS, pp. 144-153.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name.		
2. Topic: Isometric and Oblique Drawings		
B. Establish readiness.	I.B. Motivate student.	
1. Purpose: More diversity of drawings.		
2. Assignment: 3 drawings; Isometric, cabinet and cavalier.		
C. Establish effect.	I.C. Bring out need and value of material being presented.	
1. Value.		
a. Pass course.		
b. Perform better on the job.		
c. Get advanced.		
d. Be a better Engineering Aid.		
D. Overview:	I.D. State learning objective.	
1. You will be able to draw isometric and oblique drawings meeting the standards of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1	I.D.1. State information and material necessary to guide student.	
2. Ask questions.		
3. Take notes.		
4. Testable.		

OUTLINE OF INSTRUCTION | INSTRUCTOR ACTIVITY | STUDENT ACTIVITY

II. Presentation:

A. Pictorial Drawing

1. Definition

a. The representation of an object so the height, width, and depth can more realistically be seen.

b. Shows an object as it is normally seen by the observer.

2. Purpose

a. Relied entirely on conventional multi-view drawings.

(1) Multi-view drawings

(a) Complex

(b) Require time

(c) Special training

(2) Recent years gone to pictorial drawings.

(a) Convey ideas and information.

(b) Reduce costly errors.

(c) Clarity

(d) Often called graphic illustration.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
3. Types of pictorial drawings.		
a. Three (3) main groups.		
(1) Axonometric		
(2) Oblique		
(3) Perspective		
B. Axonometric Projection		
1. Principles		
a. Lines of sight are perpendicular to the planes of projection.		
b. Axis		
(1) Three		
(2) Inclined to the principal planes in orthographic.		
2. Isometric drawings	II.B.2. Slides - "Isometric Drawing", 65623, Set 3. Point out position of triangles on slides.	
a. Definition		
(1) Equal measure		
(2) Commonly used in architectural and machine drawing.		
b. Projection and drawings		
(1) Based on the revolution of views.		

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

(2) Revolved about a vertical axis - two faces show equally.

(3) Then, revolved about a horizontal axis - three faces show equally.

(4) Does not show the true size of the faces, actual measurements are foreshortened.

c. Constructing an Isometric drawing.

(1) Construct three Isometric lines - 120 degrees apart.

(2) Measurements taken from the Orthographic show in true length on the Isometric axis - Isometric lines

(3) Axis may be in 1st position - center corner or 2nd position - bottom corner.

(4) Select axis which reveals details of the object.

(5) Any line parallel to an Isometric axis is also an Isometric line - can be used in measuring.

(6) Always block in figure.

(7) Angles are not true angles on the Isometric view.

d. To draw circles and arcs - Ellipse

(1) Establish mid-points on the sides and construct diagonals from the angles closest and farthest to the viewer to the opposite sides.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

(2) Use intersections of diagonals and corners nearest and farthest from viewer as centers of arcs.

(3) For rounded surfaces construct part of an ellipse.

(4) When arc is close to half cirlce, construct entire ellipse, then cut away unneeded portion.

(5) For irregular curves use isometric axis as datum line for measurements to various points on the curve, then fill in remaining missing information.

e. Isometric sections

(1) When interior features are needed to be shown.

(2) Construct or block in figure.

(3) Remove section desired - half, full, etc.

(4) Surfaces where cutting plane passed through object are cross-hatched at 30, or 60 degree angle.

(5) Half section cross-hatching drawn in opposite directions.

f. Horizontal axis

(1) Long objects may be drawn with one axis horizontal.

(2) Isometric drawing is constructed in normal manner.

C. Oblique Projection

1. Principles

a. Shows an object with one face in true orthographic projection.

b. Axis

(1) Three (3) at various angles for receding lines.

(a) Receding lines are parallel.

c. General proportion of the object will vary, depending on placement of the object.

d. Types (3 main groups)

(1) Cavalier

(a) Same scale on all axis

(2) Cabinet

(a) Receding lines foreshortened 1/2 size.

(3) General oblique

(a) Receding lines vary in length from half to full by scale.

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OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

2. Oblique drawing and conventions

   a. Use of the axis.

      (1) 30°, 45°, 60° because of convenience are usually used.

      (2) Receding lines drawn according to type projection being done.

   b. Width, height, and depth.

      (1) Measured on three (3) axis.

      (2) Complete by drawing axis.

      (3) Hidden lines are generally omitted.

   c. Box construction applies here the same as in Isometric.

      (1) Work axis

      (2) Parallel lines complete box.

      (3) Irregular object then drawn.

   d. Non-oblique lines and angles are transferred from orthographic projections.

   e. Oblique circles and arcs.

      (1) Front face true

      (2) Receding face, ellipse

         (a) Four-center method

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

D. Isometric and Oblique Dimensions; the same rules apply to both.

1. Place all dimensions in the plane to which they apply.
2. Dimension lines and extension lines follow axis of respective type of drawing.
3. Lettering is perpendicular to the dimension lines.

III. Application:

A. Questions and Discussion

QUESTIONS:	ANSWERS:
a. What type of axonometric drawings was discussed during this lecture?	a. Isometric
b. A cabinet drawing would be classified as a/an ________________ type drawing?	b. Oblique
c. How do we define a non-isometric line in axonometric projection?	c. Line not parallel to primary axis.
d. How far apart are the axis in isometric drawings.	d. 120 degrees
e. What method is used to draw circles and arcs in axonometric projection? Oblique?	e. Four center method, both.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
B. Practical Performance	III.B. Pass out and explain SCBT 420.1 EA JS 1.2.7.1 "Isometric and Oblique Drawings" guide students in application of making isometric and oblique drawings. Evaluate student performance on completed work.	III.B. Practice and work job sheet requirements.
IV. Summary:		
A. Pictorial Drawing		
1. Definition		
2. Purpose		
3. Types of Pictorial Drawings		
B. Axonometric Projection		
1. Principles		
2. Isometric Drawings		
a. Definition		
b. Projection and drawings		
c. Construction		
d. Circles and arcs in isometric		
e. Isometric sections		
f. Horizontal axis for long objects		

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

C. Oblique Projection

   1. Principles

   2. Drawings and conventions

D. Isometric and Oblique Dimensions

V. Test:

A. Demonstrate ability to make good isometric and oblique drawings using conventional drafting equipment.

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SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

JOB SHEET

TITLE: Isometric and Oblique Drawings

INTRODUCTION: The purpose of this job sheet is to guide you in the practical work assignment in pictorial drawings. After assembling the necessary tools and materials, read over the procedure rapidly to get a general picture of the drawing requirements, then complete each of the drawings.

REFERENCES:

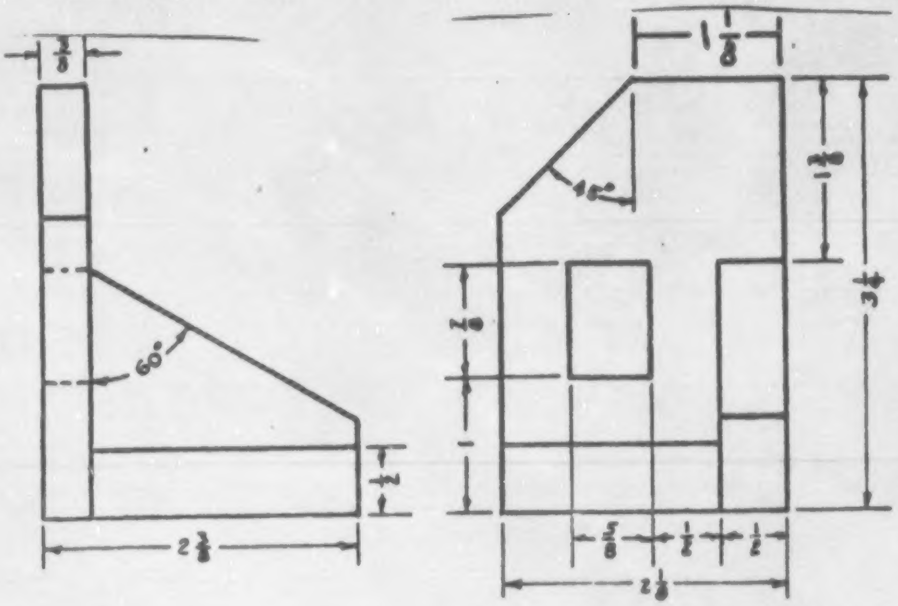
1. Military Standard, Engineering Drawing Practices, MIL-STD-100A, Pages 9 and 45.
2. Engineering-Technical Drafting and Graphics, 2nd Edition, American Technical Society, Pages 443-456.
3. Engineering Aid 3 & 2, NAVPERS 10634-B, pp. 144-153.

TOOLS, EQUIPMENT AND MATERIALS:

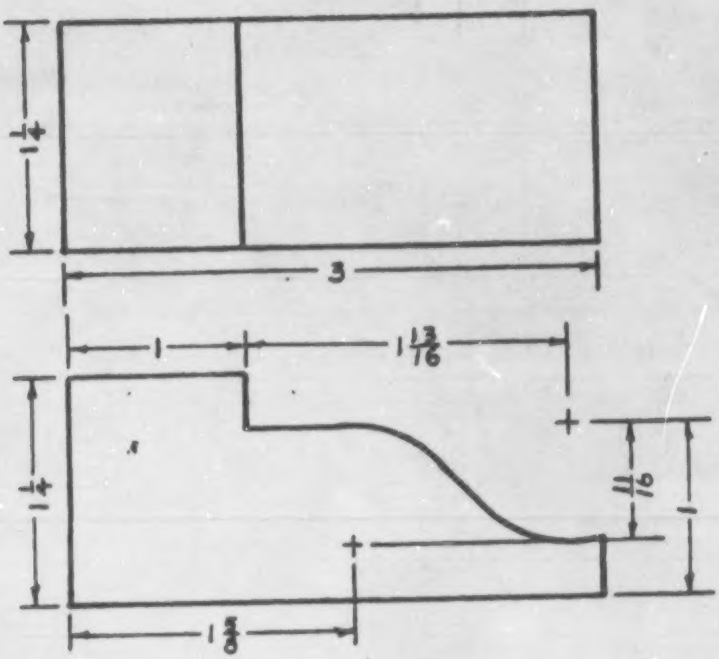
1. Equipment.
    a. Architects scale.
    b. Triangles, 30° - 60° and 45°
    c. Compass, bow.
2. Material.
    a. Pencils.
    b. Tracing paper, 3 sheets "A" size.
    c. Drafting tape
    d. Dry cleaning pad.

PROCEDURES: On an "A" size sheet, sketch out the solution to each of the following three problems for instructor approval before proceeding to do the final drawings. All sketches will meet the minimum requirements of Topic 1.2.2, "Basic Sketching".

Draw each drawing on "A" size sheets of tracing paper, complete with proper border in accordance with MIL-STD-100A, Page 9. Omit title and revision blocks. Layout procedures should be in accordance with "Drafting and Graphics", Pages 443-455. Complete drawings must meet the acceptable standards of Evaluation Guide 420.1 EA EG 1.2.0.1 for each of the 10 points. Make a print of each drawing following procedures set forth in Job Sheet SCBT 420.1 EA JS 1.2.8.1



1. Make a full scale isometric drawing of the object above. The drawing shall include all mechanical dimensions necessary and applied according to the pictorial-plane dimensioning system contained in "Drafting and Graphics", Pages 447-449.


1 1/4
3
1
1 13/16
1 1/4
11/16
1
1 5/8

3. Make a full scale cavalier projection of the above object and include all mechanical dimensioning applied according to the pictorial-plane dimensioning system.

QUESTIONS:

1. None

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SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

Classification: Unclassified

Topic: Reproduction Processes

Average Time: 1 Period (Class) 1 Period (Pract)

Instructional Materials:

A. Texts.

1. Engineering Aid 3 & 2, NAVPERS 10634-B
2. Engineering-Technical Drafting & Graphics, 2nd Edition.

B. References:

1. Architectural Drawing & Light Construction, Pages 206-209.
2. Diazit Space Saver, Instruction Manual.
3. Diazit Pump-It, Instruction Manual.

C. Tools, Equipment and Materials:

1. Equipment.
    a. Diazit Space Saver Printer/Developer.
    b. Diazit Pump-It Ammonia Pump.
2. Material.
    a. Diazo Print Paper.

Terminal Objective: Upon completion of this unit the student will be able to use the tools of a draftsman and perform the techniques and procedures related to basic drafting. All problem solutions submitted by the student as his finished product will meet the minimum requirements of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1

Enabling Objectives: Upon completion of this topic the student will be able to fold and file prints as well as operate a Diazo Reproduction Machine to reproduce copies of his drawings completed and noted in the requirements of the other topics of this unit. A minimum of one completed drawing or exercise from each topic noted to be reproduced (except Topic 1.2.1 "Lettering".) He will be able to prepare the Diazo Reproduction Machine for operation, operate the machine at the proper speed with the proper amount of developing agent to produce copies of his drawings to give a line resolution equal to the line value or opaqueness of the original drawings, and secure the machine without damage to the exposure and developing section.

Criterion Test: The student will make a legible print of a drawing furnished by the instructor, using the dry Diazo method. Students will fold a "F" size print to 8½ x 11" following the procedures set forth in Engineering Aid 3 & 2, NAVPERS 10634-B with 100 percent accuracy.

Homework: Read

Engineering Aid 3 & 2, NAVPERS pp. 157-163.

Drafting & Graphics, pp. 388-397.

D. Training Aids and Devices:

1. Transparencies.

   a. 11CS-5600.101T-8 Thermofax Machine.

   b. 11CS-5600.101T-5 Photocomposing Machine.

   c. 11CS-5600.101T-6 Xerox 720.

   d. 11CS-5600.101T-7 Ozalid Streamliner.

2. Locally Prepared Material.

   a. Job Sheet.

      (1) SCBT 420.1 EA JS 1.2.8.1 "Diazo Printing".

E. Training Aids Equipment:

1. Overhead Projector.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to the lessson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name.		
2. Topic: Diazo Printing.		
B. Establish readiness.	I.B. Motivate student.	
1. Purpose.		
a. Preserve the original.		
b. Most commonly used.		
c. Simplifies your job as an Engineering Aid.		
C. Establish effect.	I.C. Bring out need and value of material being presented.	
1. Value.		
a. Knowledge of methods makes better quality of reproduction.		
D. Overview:	I.D. State learning objectives.	
1. You will be able to operate a Diazo Reproduction Machine to reproduce copies of your drawings, as required for all topics in the Drafting Phase.	I.D.1. State information and material necessary to guide student.	
2. Ask questions.		
3. Take notes.		
4. Testable.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
II. Presentation		
A. Graphic Reproduction Processes.		
1. Four major classifications.		
a. Heat process - Thermofax.	II.A.1.a. Show Transparency 11CS-5600.101T-8, Thermofax Machine.	
b. Silver process - Photography.	II.A.1.b. Show Transparency 11CS-5600.101T-5, Photocomposing Machine.	
c. Electrostatic process - Xerox.	II.A.1.c. Show Transparency 11CS-5600.101T-6, Xerox 720.	
d. Diazo process - Diazit, Ozalid, etc.	II.A.1.d. Show Transparency 11CS-5600.101T-7, Ozalid Streamliner.	
B. Diazo Process.		
1. Ammonia vapor process - most commonly used.		
2. Positive copy - line on white paper.		
3. Light sensitive - chemical coating on paper.		
4. Techniques for producing.		
a. Dry-developing - Ammonia vapor.		
b. Semi-dry - Moist developing.		
5. Formula ingredients.		
a. Diazonium salt - light yellow on paper.		
b. Coupler.		

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(1) Dye or color.		
6. Advantages.		
a. More versatile.		
b. Fast.		
c. Dry.		
d. Complete line of material - prints, transparencies, cover stock (colors) etc.		
e. Intermediate copy - Sepia.	II.B.6.e. Show example of sepia.	
7. Disadvantages.		
a. Ammonia vapor (now have masking agent).		
b. Semi-permanent - will fade, particularly in sunlight.		
8. Trademark.		
a. By company name, Diazit or Ozalid' - General Airlines Corporation.		
C. Diazit Space-Saver Operating Procedures.	II.C. Demonstrate each step on machine. Allow each student to try one set-up.	II.C. Students move from desk to machine for demonstration.
1. Steps for operations.		
a. Turn on machine.		
(1) 20 minute warm-up - idle speed.		
b. Turn on pump - only when not automatic, follow pump instruction with machine.		

OUTLINE OF INSTRUCTION — INSTRUCTOR ACTIVITY — STUDENT ACTIVITY

c. Set exposure speed after warm-up.

d. Test run - for exposure spedd.

e. Feed original and print paper.

f. Separate original and print paper.

g. Develop print.

D. On-The-Spot Trouble Shooting - when operating.

1. When paper binds or wraps around developer.

a. Do not pull on sheet.

b. Stop machine.

c. Cut print above pick-off bar.

II.D.1.c. Show pick-off bar on machine.

d. Note: Some models have reverse for removing copies that bind.

2. Cautions.

a. Keep nuts, screws, etc. tight, do not loosen, see manufacturer's manual.

b. Never use stiff paper in machine, must have bending quality.

3. Running time.

a. More economical to let run long periods rather than to turn on and off, lamp will last longer.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

4. Turning off machine.

    a. Free all material from machine, paper.

    b. Slow speed to idle.

    c. Shut down ammonia pump - follow machine instruction for various types of pumps.

    d. Place paper around ammonia roll.

    e. Turn off machine.

E. Continual Trouble-Shooting

1. Wrinkled tracing or original.

    a. Printer belts too tight - see manufacturer's manual.

2. Blurred prints -

    a. Printer belts too loose - adjust according to manufacturer's manual.

3. Uneven printing or slow printing speed.

    a. Not warm enough or blockage in ammonia system.

4. Lamp replacement - follow manufacturer's manual instructions.

F. Maintenance

1. Oil all moving parts every three months.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

2. Inspect drive motor brushes every three months.

G. Safety Factors

1. Keep fingers and clothing out of machine.

2. Keep ammonia away from face.

   a. If ammonia splashes in eyes, wash with fresh water thoroughly and seek medical attention IMMEDIATELY.

H. Filing Drawings

1. The protected stowage of a large number of items with:

   a. Economy of space.

   b. Readily located.

2. Records (Index)

   a. Log book.

   b. 3 x 5 cards.

   c. Cross reference.

OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

3. Stowage cabinets
   - a. Map drawer.
   - b. Shallow drawer file cabinet.
   - c. Deep-drawer.
4. Stowage of materials
   - a. Originals.
     - (1) A and B deep drawer.
     - (2) C and above, shallow or map drawer.
     - (3) Roll size-tubes.
   - b. Prints
     - (1) Regardless of size folded.
     - (2) Filed in deep-drawer file.
     - (3) Demonstrate how to fold prints.
       - (a) Folding guides.
       - (b) Fold the print into 10 7/8 in. lengthwise accordian pleat folds first.

1 Face down first, turning up the edge with the drawing number.

2 Continue accordion pleats.

(c) Place face with drawing number down after accordion pleats are completed.

(d) Fold first 8½" fold crosswise to accordion pleats. (Starting with drawing number edge).

(e) Completed size (8½ x 11").

c. Data

(1) Filed by drawing number in separate drawer or cabinet.

(2) Usually with print.

d. Stick file.

(1) Set of prints on each job.

(2) Used by office and field personnel.

(3) As-built records.

OUTLINE OF INSTRUCTION

III. Application:		
A. Operation of Diazit Space Saver		
1. Handout "Diazo Printing".	III.A.1. Distribute Handout SCBT 420.1 EA JS 1.2.8.1 "Diazo Printing".	
2. Student operation - making prints.	III.A.2. Supervise students operating machine.	III.A.2. Operate machine to make prints following job sheet.

IV. Summary:

A. Five Major Types of Graphic Reproduction Processes.

B. How The Diazo Process Works.

C. The Operation of the Diazit Space Saver.

D. Trouble-Shooting the Diazit Space Saver.

E. The Maintenance of the Diazit Space Saver.

F. Safety Factors.

V. Test:

A. Demonstrate ability to make good prints using the Diazit Space Saver.

1. Evaluation will be part of the drafting phase.

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SPECIAL CONSTRUCTION BATTALION TRAINING (SCBT) 420.1

JOB SHEET

TITLE: Diazo Printing.

INTRODUCTION: Working drawings go to the shop or field in the form of prints made from the original drawings. In NMCB's the most common printing machine is a lightweight, highly-portable Diazo Printer similar to the Diazit Space Saver. The purpose of this job sheet is to guide you in the proper use of the Diazit Space Saver for making prints.

REFERENCES: None

TOOLS, EQUIPMENT AND MATERIALS:

1. Equipment.
    a. Diazit Space Saver Printer/Developer.
    b. Diazit Pump-It Ammonia Pump.
2. Material.
    a. Original drawing.
    b. Diazo paper.

PROCEDURES:

1. Warm up printer/developer.
    a. Turn printer/developer on and set exposure speed control to slow (2-5).
        (1) Allow at least 20 minutes for the developer to reach operating temperature.
2. Charge developer with ammonia.
    a. Turn pump-it on for approximately one minute.
        (1) Check tubing to insure ammonia flow. The pump-it will adequately charge developer running 20-50 seconds.
3. Set exposure speed.
    a. 5-6 for ink or 6-7 for pencil.
        (1) Exposure speed will vary with type of print paper and tracing paper.

4. Feed original and print paper into printer.

   a. Original face up on sensitized side of Diazo material.

      (1) Both material can be pulled out of the printer section at any time without stopping.

5. Develop print.

   a. Separate print from original and feed it into developer.

      (1) Exposed sheet should be smoothed out, taut, and straight with a good sized, free loop before feeding into developer section. Do not try to pull a sheet back out of the developer section.

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Classification: Unclassified

Topic: Tracing

Average Time: 1 Period (Class) 8 Period (Pract)

Instructional Materials:

A. Texts.

1. None.

B. References:

1. Engineering Drawing, French & Vierck 10th Edition

C. Tools, Equipment and Materials:

1. See Annex III of Curriculum

D. Training Aids and Devices:

1. None

E. Training Aids Equipment:

1. None

Terminal Objective: Upon completion of this unit the student will be able to use the tools of a draftsman and perform the techniques and procedures related to basic drafting. All problem solutions submitted by the student as his finished product will meet the minimum requirements of Evaluation Guide SCBT 420.1 EA EG 1.2.0.1

Enabling Objectives: Upon completion of this topic the student will be able to trace drawings following the procedures set forth in this instructors guide. Individual instructor guidance and study texts can be utilized in the performance of the requirements of this topic. The tracing submitted by the student as his finished product will be 100% accurate for all details when compared with the original drawing and will meet the acceptable standards of SCBT 420.1 EA EG 1.2.0.1 for all 10 parts of a good drawing.

Criterion Test: The student will demonstrate his ability to trace a drawing following the procedures set forth by this instructor guide. The tracing submitted by the student as his finished product will be 100% accurate for all details when compared with the original drawing and will meet the acceptable standards of SCBT 420.1 EA EG 1.2.0.1 for all 10 parts of a good drawing.

OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
I. Introduction to lesson.		
A. Establish contact.	I.A. Introduce self and topic.	
1. Name.		
2. Topic: Tracing.		
B. Establish readiness.	I.B. Motivate student.	
1. Purpose.		
2. Assignment.		
C. Establish effect.	I.C. Bring out need and value of material being presented.	
1. Value.		
a. Pass course.		
b. Perform better on the job.		
c. Get advanced.		
d. Be a better Engineering Aid.		
D. Overview:	I.D. State learning objective.	
1. You will be able to trace a drawing.	I.D.1. State information and materials necessary to guide student.	
2. Ask questions.		
3. Take notes.		
4. Testable.		

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OUTLINE OF INSTRUCTION | **INSTRUCTOR ACTIVITY** | **STUDENT ACTIVITY**

II. Presentation

A. Tracing - The art of copying a detail or construction drafting using either pencil or ink.

1. Drawings are traced for many reasons.

a. Poor line quality on original.

b. Original copy required by other agencies.

c. Damaged originals.

d. Etc.

2. Tracing Media

a. Characteristics to look for.

(1) Good transparency for reproduction.

(2) Suitable "Tooth" for pencil work.

(3) Good erasing qualities.

(4) Non-yellowing qualities.

(5) Strength and resistance to tearing.

(6) Resistance to brittleness and shrinkage.

OUTLINE OF INSTRUCTIONS **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

b. Types

(1) Tracing cloth.

(a) Is a semi-transclucent material.

(b) Made by impregnating linen with starch.

(c) Used finished work or tracing; usually in ink.

(d) Is very easily damaged by water.

(e) Very susceptible to size. change.

(2) Pencil cloth

(a) Usually has one or both sides prepared to take pencil.

(b) Basic qualities the same as tracing cloth.

(3) Mylar (Polyester film)

(a) Is a translucent, tear and stretch resistant plastic.

(b) Maintains accuracy of drawing or permanent information.

(c) Takes pencil and ink very well.

(d) Pencils developed just for working on mylar.

(4) Tracing glass

(a) A transparent material.

(b) Has a high dimensional stability.

(c) Very good for ink or pencil.

(d) Used mostly in tool and die work.

(5) Tracing paper

(a) A thin transparent paper.

1 Either left natural or treated with a transparent. substance.

2 Treated paper is called vellum.

(b) Used for all types of pencil or ink work.

(c) Comes in may different grades but in general has all those characteristics required or a good tracing paper when the rag content is high.

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OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**

3. General Rules

   a. Speed and accuracy are the most important qualities to strive for.

   b. Never trace a drawing lightly and heavy in later.

   c. Never trace from copies, redraw.

   d. Keep hands, arms and body off tracing.

   e. Do not start a view you can't finish during your present working day.

   f. Cover completed views.

   g. Follow rules of pencil and ink drawing.

4. Techniques In Preparation For Drawing Or Tracing

   a. Preparation.

      (1) Lights.

         (a) If possible, should come from left.

         (b) Non-Glare type.

         (c) Above 50 candle power.

(2) Board

(a) Inclined 10° to 15° from horizontal.

(b) Clean.

(c) Reference area away from work area.

(3) Instruments

(a) Place most used on hand.

(b) Keep in same place, save time.

(c) Don't clutter work area.

(4) Paper

(a) Tape down sheet.

1 Upper left to lower right.

(5) Pencils

(a) Should have an F, H, 2H, and 3H pencil handy, sharpened.

(b) Should have a wedge or chisel for long straight lines and a conical for normal work.

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OUTLINE OF INSTRUCTION

INSTRUCTOR ACTIVITY

STUDENT ACTIVITY

b. At this point let's discuss "What Is A Good Drawing?"

(1) Visible lines.

(a) Edges of object.

(2) Dimensions.

(a) Numerical value expressed in appropriate units of measure.

(3) Notes.

(a) Written information which usually can't be shown in other ways.

(4) Line conventions.

(a) All lines not a visible line.

(5) Tangents.

(a) Intersections of curved and straight lines.

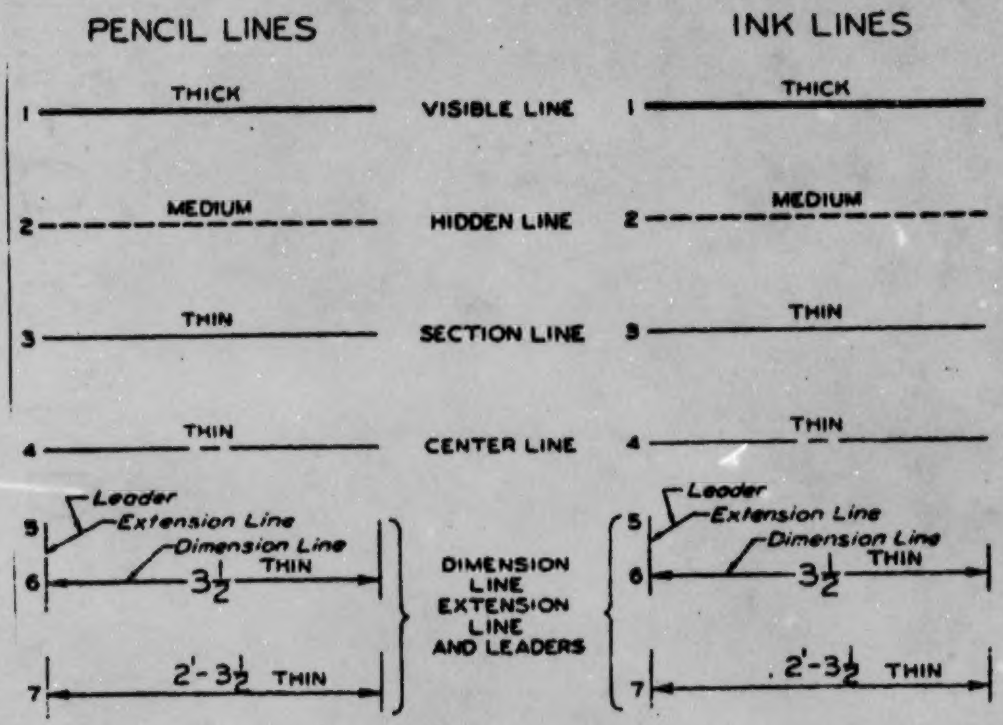
(6) Format.

(a) Overall appearance of drawing.

(7) Lettering.

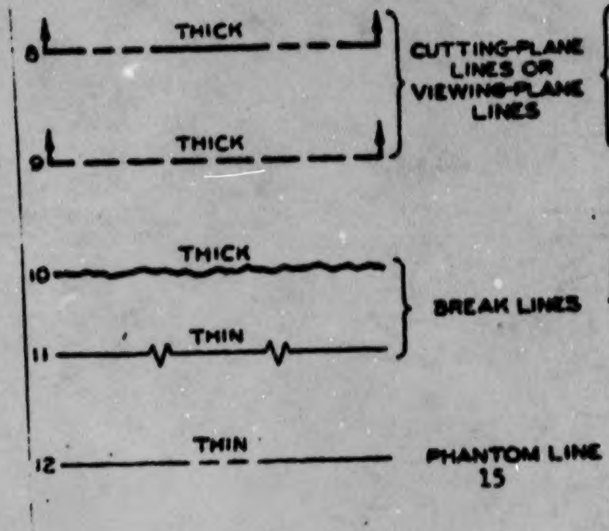
(a) Only letters.

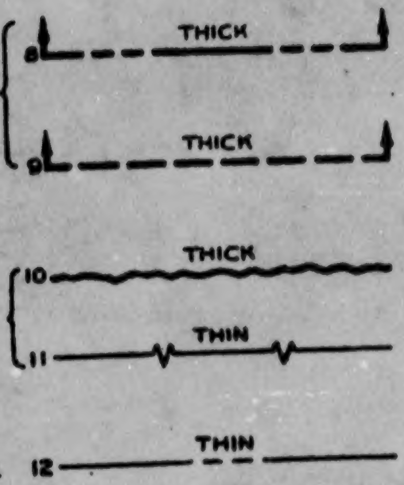
OUTLINE OF INSTRUCTION	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
(8) Accuracy.		
(a) Precision or exactness; correctness.		
(9) Solution.		
(a) How well you completed your assignment.		
c. Alphabet of lines.	II.A.4.c. Draw each line on C/B and explain how it's used and drawn properly.	


PENCIL LINES
INK LINES
1 THICK
VISIBLE LINE
1 THICK
2 MEDIUM
HIDDEN LINE
2 MEDIUM
3 THIN
SECTION LINE
3 THIN
4 THIN
CENTER LINE
4 THIN
5 Leader
Extension Line
6 Dimension Line
3½ THIN
7 2'-3½ THIN
DIMENSION LINE EXTENSION LINE AND LEADERS
5 Leader
Extension Line
6 Dimension Line
3½ THIN
7 2'-3½ THIN

185

OUTLINE OF INSTRUCTION **INSTRUCTOR ACTIVITY** **STUDENT ACTIVITY**


8
THICK
9
THICK
CUTTING-PLANE LINES OR VIEWING-PLANE LINES
10
THICK
11
THIN
BREAK LINES
12
THIN
PHANTOM LINE
15


8
THICK
9
THICK
10
THICK
11
THIN
12
THIN

d. Order of drawing.

(1) Pencil.

(a) Select sheet.

(b) Choose scale.

(c) Draw center lines for each view.

(d) Draw views, dominant to minor.

(e) Check.

(f) Dimension.

(g) Guide lines, letter.

(h) Title.

(i) Recheck.

(2) Ink.

(a) Circles - Smallest to largest.

(b) Dashed circles.

(c) Irregular curves.

(d) Straight lines - in order - horizontal, vertical, inclined.

(e) Hidden lines - Same order as (4).

(f) Center lines.

(g) Extension and dimension lines.

(h) Arrowheads and dimensions.

(i) Section lines.

(j) Letter notes and titles.

(k) Border.

(l) Check.

OUTLINE OF INSTRUCTIONS	INSTRUCTOR ACTIVITY	STUDENT ACTIVITY
III. Application	III.A. Questions	III.A. Answers
A. Discussion	1. What are the ten (10) parts of a good drawing?	1. Visible lines, dimensions, notes, line conventions, tangents format, lettering, accuracy, solution.
	2. What characteristics should a good tracing paper have.	2. a. Good transparency for reproduction b. Tooth for pencil work. c. Good erasing qualities. d. Nonyellowing qualities. e. Strength and resistance to tearing. f. Resistance to brittleness and shrinkage.
	3. What is the most important qualities to strive for in tracing a drawing.	3. Speed and Accuracy.
B. Practical Performance	III.B. Passout copies of drawing No. ____________ and have students trace same. Read and explain criterion test and have students perform it.	III.B. Trace drawing No.

IV. Summary.

- A. Tracing
  - 1. Reasons for.
  - 2. Tracing media.
  - 3. General rules.
  - 4. Techniques in preparations.

V. Test.

- A. None

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6-3

CHAPTER 4

DRAFTING: GEOMETRIC CONSTRUCTIONS

As an Engineering Aid, you will be concerned principally with line drawings. A line drawing is one in which the graphic representation consists exclusively of lines, as distinguished from a drawing in which the representation is made up of, or includes, light and dark areas.

A line in a line drawing may be a straight line, a circle, an arc of a circle, or a noncircular curve; or it may be a line which is a compound of more than one of these basic types of lines. A noncircular curve may be a "random" curve; or it may be one of the noncircular curves which are derived from conic sections; or it may be a noncircular curve derived from the "spiral of Archimedes." The noncircular curves derived from conic sections are the ellipse, the parabola, and the hyperbola.

As a draftsman, you must be able to "construct" any of the various types of straight and curved lines used in a line drawing. You must also be able to "construct" lines at specified angles to each other, and to "construct" the various types of plane figures, circular curves, and noncircular curves. The general term applied to this phase of draftsmanship is "geometric constructions." This chapter provides information that will aid you in making different types of geometric constructions that may involve you in your duties as a draftsman.

CONSTRUCTIONS INVOLVING ANGLES

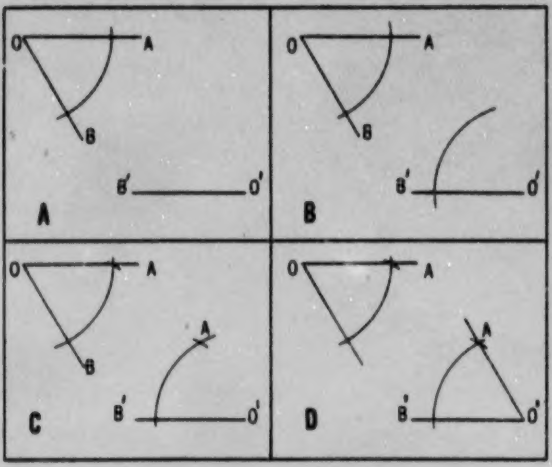
You already know how to lay off an angle of given size with a protractor, or trigonometrically by the use of the tangent or the chord method.

TRANSFERRING AN ANGLE

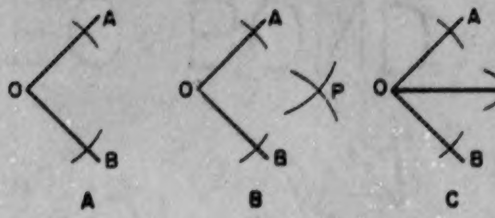
There is a geometric construction for laying off, on another part of the same drawing or on a different drawing, an angle equal in size to one which is already drawn. This procedure, called "transferring" the angle, is illustrated in figure 4-1. Here, the draftsman desired to lay off from O' a line which would make an angle with B'O' equal to angle BOA. To do this, draw an arc through OB and OA, with O as a center, as shown in figure 4-1(A). Then, draw an arc of the same radius from B'O', with O' as a center, as shown in figure 4-1(B). Next, measure the length of the chord of the arc between OB and OA and lay off the same length on the arc from B'O'. A line drawn from O' through A' makes an angle with B'O' equal to angle BOA.

BISECTING AN ANGLE

To bisect an angle means to divide it in half. If you know the size of the angle, you can bisect it by simply dividing the size by 2 and laying off the result with a protractor.



23.227
Figure 4-1.—Transferring an angle.

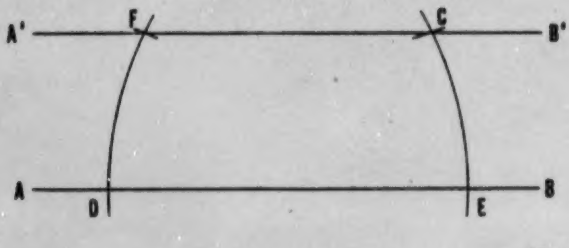


23.226
Figure 4-2.—Bisecting an angle.

Geometric construction for bisecting an angle is shown in figure 4-2. To bisect the angle AOB, first lay off equal intervals from O on OA and OB. With the ends of these intervals as centers, strike intersecting arcs of equal radius at P. Draw a line from O through the point of intersection of the arcs, P. The line OP bisects angle AOB.

CONSTRUCTIONS INVOLVING STRAIGHT LINES

In the preceding chapter, you learned how to draw a line parallel to another line by the use of a straightedge and a sliding triangle. Another method of drawing parallel lines is illustrated in figure 4-3. Here the line was to be drawn through given point C. To draw a line through C parallel to AB, place the needlepoint of a compass on any point D on AB, and strike arc CE. Shift the needlepoint to E, maintaining the same radius, and strike arc DF. Set compass or dividers to chord of arc CE, and lay off the chord DF from D, thus locating point F. A line drawn through F and C is parallel to AB.



45.164
Figure 4-3.—Drawing a line through a given point, parallel to another line.

Figure 4-4 shows another method of drawing one line parallel to another, this one being used when the second line is to be drawn at a given distance from the first. To draw a line parallel to AB at a distance from AB equal to CD, set the compass to the length of CD and from any points E and F on AB strike two arcs. A line A'B' drawn tangent to (barely touching) the arcs is parallel to AB, and located CD distance from AB.

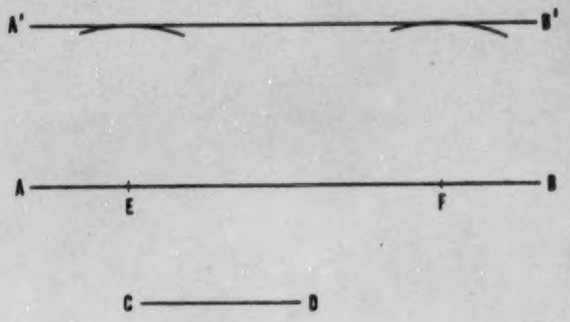
In the preceding chapter, you learned how to draw a line perpendicular to another by the use of a straightedge and a sliding triangle. Other methods of solving this problem are explained below.

Figure 4-5 shows a method of dropping a perpendicular from a given point to a line. To drop a perpendicular from point P to AB, set the needlepoint of a compass at P and strike an arc intersecting AB at C and D. With C and D as centers and any radius larger than one-half of CD, strike arcs intersecting at E. A line from P through E is perpendicular to AB.

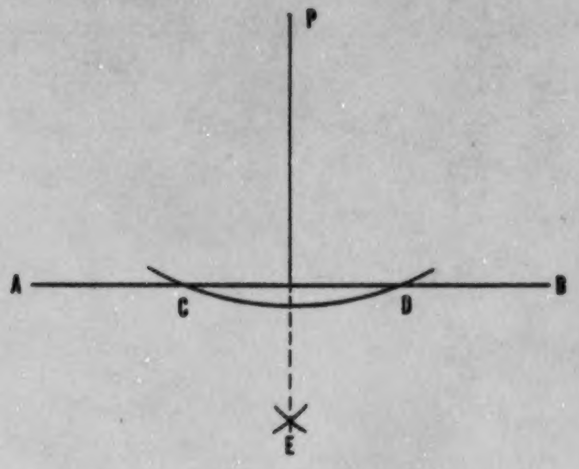
Figure 4-6 illustrates a method of erecting a perpendicular from a given point on a line. To erect a perpendicular from point P on AB, set a compass to any convenient radius a[illegible] with P as a center, strike arcs intersecting AB at C and D. With C and D as centers and any radius larger than one-half of CD, strike arcs intersecting at E. A line from P through E is perpendicular to AB.

BISECTING A LINE

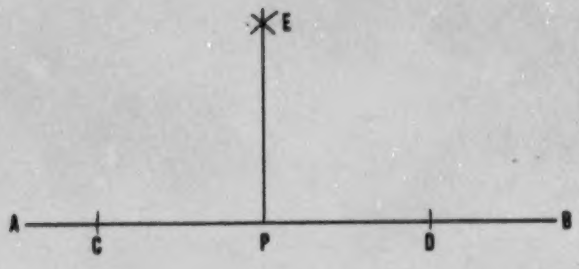
A line can be bisected by trial-and-error with dividers—that is, by setting the dividers



45.165
Figure 4-4.—Drawing a parallel line at a g[illegible] distance from another line.



28.26
Figure 4-5.—Dropping a perpendicular from a given point to a line.



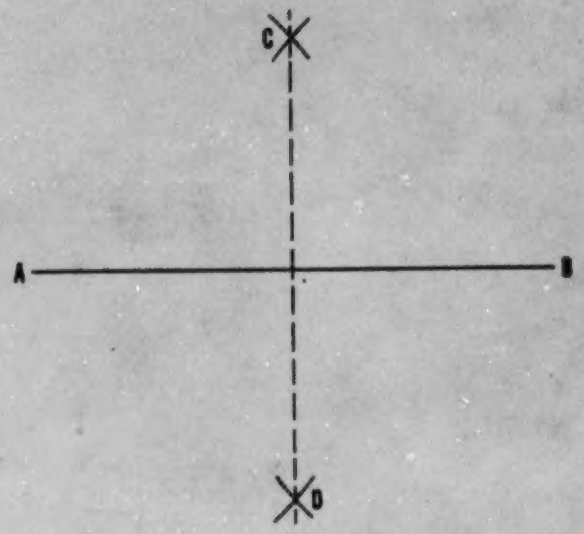
11.216A
Figure 4-6.—Erecting a perpendicular from a given point on a line.

to various spreads until you get one which tries out as one-half the length of the line.

Geometric construction for bisecting a line is shown in figure 4-7. To bisect the line AB, use the ends of the line, A and B, as centers, set a compass to a radius greater than one-half the length of AB, and strike arcs intersecting at C and D. A line drawn from C through D bisects AB.

DIVIDING A LINE INTO ANY NUMBER OF EQUAL PARTS

A line may be divided into more than two equal parts by trial-and-error with the dividers.



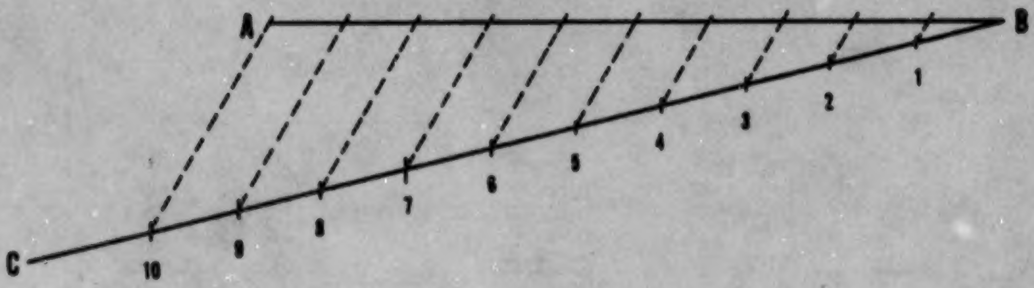
11.216
Figure 4-7.—Bisecting a line.

Geometric construction for dividing a line into any number of equal parts is shown in figure 4-8. To divide AB into 10 equal parts, draw a ray line CB from B at a convenient acute angle to AB. Set a compass to a spread less than one-tenth of the length of CB, and lay off this interval 10 times from B on CB. Draw a line from the 10th interval to A, and project the other points of intersection from CB to AB by lines parallel to the first one. The projected points of intersection divide AB into 10 equal parts.

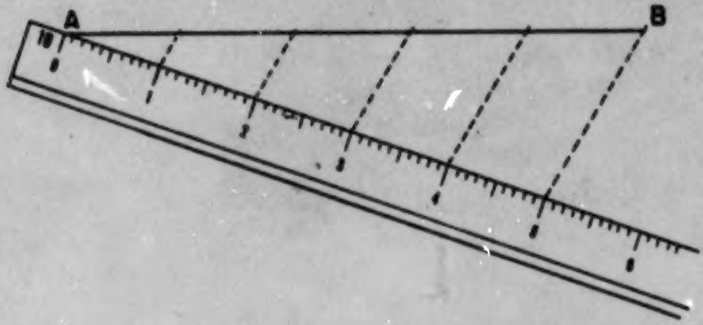
Figure 4-9 shows how you can use a scale to lay off equal intervals on the ray line.

PROPORTIONAL PARTS

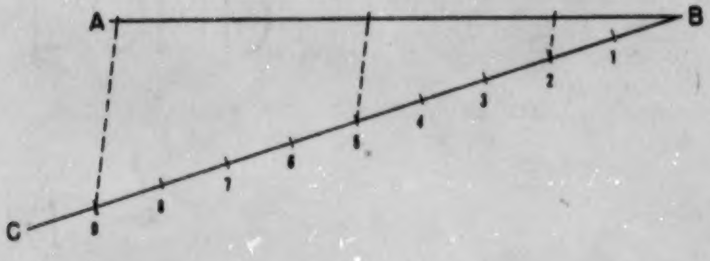
Figure 4-10 shows a method of dividing a line into given proportional parts. The problem here is to divide the line AB into parts which are proportional as 2:3:4. Lay off ray line CB from B at a convenient acute angle to AB. Set a compass to a convenient spread, and lay off this interval from B on CB a number of times equal to the sum of the figures in the proportion (2+3+4=9). Draw a line from the point of intersection of the last interval to A, and use a straightedge and sliding triangle to project the second and fifth intercepts on CB to AB by lines parallel to the first one. The projected intercepts divide AB into segments which are proportional as 2:3:4.


A
B
C
1
2
3
4
5
6
7
8
9
10

23.228
Figure 4-8.—Dividing a line into any number of equal parts.


A
B
10
0
1
2
3
4
5
6

45.167
Figure 4-9.—Using a scale to lay off equal intervals on random line.


A
B
C
1
2
3
4
5
6
7
8
9

45.168
Figure 4-10.—Dividing a line into proportional parts.

Here again you could use a scale to lay off 9 equal intervals on CB.

PARTS ACCORDING TO A GIVEN RATIO

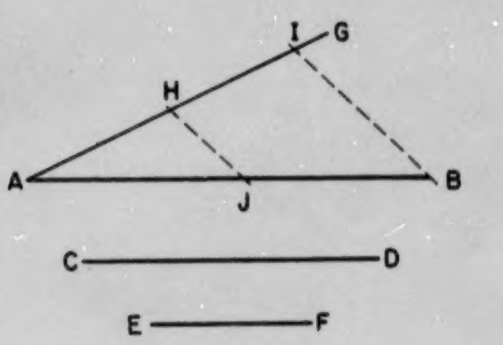
You may be required to divide a line into parts so that the ratio between the whole line and one of the parts is the same as that between two other lines. A method of doing this is shown in figure 4-11. Here it is required that AB be divided so that the ratio between AB and a part of AB is the same as the ratio between CD and EF. From A draw a ray line AG at a convenient acute angle from AB. On AG lay off AH equal to EF and AI equal to CD. Draw a line from I to B, and use a straightedge and sliding triangle to project H to J on a line parallel to IB. The ratio of AB to AJ is the same as that of CD to EF.

CONSTRUCTIONS INVOLVING PLANE FIGURES

In this section, we will explain how to construct a triangle, rectangle, square, circle, regular polygon, regular pentagon, hexagon, octagon, and so on. An understanding of the geometrical construction of plane figures, as presented in this section, is essential to the Engineering Aid because of the frequent occurrence of plane figures in engineering drawings.

TRIANGLE: THREE SIDES GIVEN

To draw a triangle with three sides given, first draw a straight line AB, equal in length to one of the given sides. With A as a center, strike an arc with radius equal to the given length of the second side. With B as a center, strike an intersecting arc with radius equal to the length of the third side. Draw lines from A and B to the point of intersection of the arcs.



45.169
Figure 4-11.—Dividing a line into parts according to a given ratio.

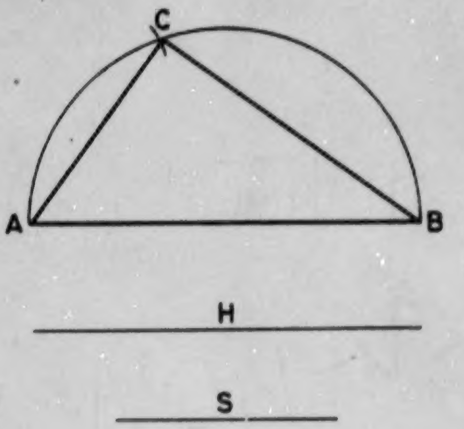
RIGHT TRIANGLE: HYPOTENUSE AND ONE SIDE GIVEN

Figure 4-12 illustrates a method of drawing a right triangle when the hypotenuse and one side are given. The line H is the given hypotenuse; the line S is the given side. Draw AB equal to H. Locate the center of AB (by bisection), and with the midpoint as a center and a radius equal to one-half of AB, draw the semicircle from A to B as shown. Set compass or dividers to the length of S, and with A as a center strike an arc intersecting the semicircle at C. Draw AC and BC.

EQUILATERAL TRIANGLE: LENGTH OF SIDE GIVEN

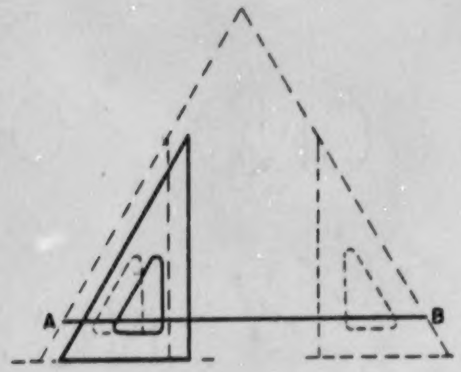
To construct an equilateral triangle when the length of a side is given, you can follow the method previously described for constructing a triangle when the length of each side is given. The sides of an equilateral triangle are equal in length.

Each angle in an equilateral triangle measures 60°. This fact is applied in the method of constructing an equilateral triangle with given length



45.170
Figure 4-12.—Constructing a right triangle with hypotenuse and one side given.

of side which is shown in figure 4-13. Simply use a 30-60° triangle and a T-square or straightedge to erect lines from A and B at 60° to AB.

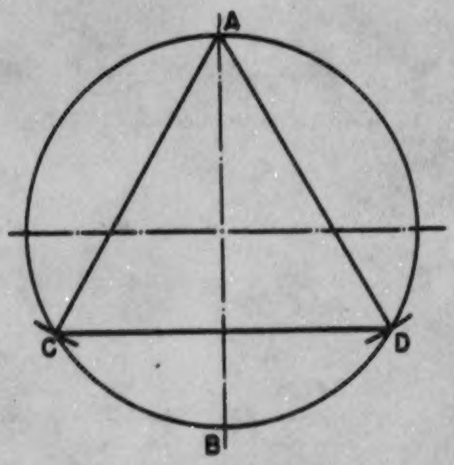


23.240.1A
Figure 4-13.—Equilateral triangle with given length of side AB.

EQUILATERAL TRIANGLE IN GIVEN CIRCUMSCRIBED CIRCLE

A "circumscribed" plane figure is one which encloses another figure, the circumscribed figure being tangent to the extremities of the enclosed figure. An "inscribed" plane figure is one which is enclosed by a circumscribed figure.

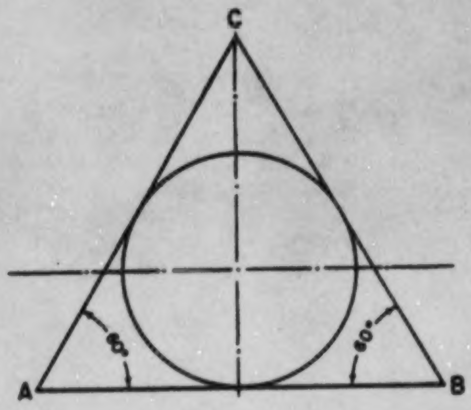
Figure 4-14 shows you how to inscribe an equilateral triangle within a given circumscribed circle. Draw a vertical centerline intersecting the given circle at A and B. With B as a center and a radius equal to the radius of the circle, strike arcs intersecting the circle at C and D. Lines connecting A, C, and D form an equilateral triangle.



23.240.1B
Figure 4-14.—Equilateral triangle in given circumscribed circle.

EQUILATERAL TRIANGLE ON GIVEN INSCRIBED CIRCLE

Figure 4-15 illustrates one method of circumscribing an equilateral triangle on a given inscribed circle. Draw AB parallel to the horizontal centerline of the circle and tangent to the circumference. Then use a 30-60° triangle to draw AC and BC at 60° to AB and tangent to the circle.

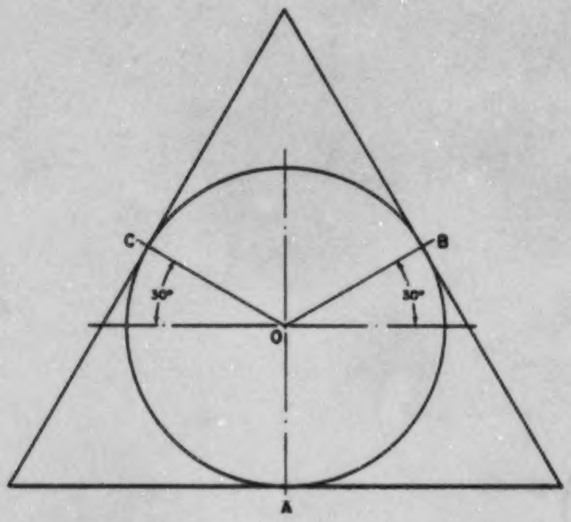


23.240.1C
Figure 4-15.—Equilateral triangle on given inscribed circle: one method.

Another method of accomplishing this construction is shown in figure 4-16. Draw radii at 30° to the horizontal centerline of the circle, intersecting the circumference at C and B. There is a third point of intersection at A, so that you now have three radii: OA, OB, and OC. Draw the sides of the triangle at A, B, and C, tangent to the circle and perpendicular to the relevant radius.

RECTANGLE: GIVEN LENGTH AND WIDTH

To construct a rectangle of given length and width, draw a horizontal line AB with the T-squa equal to the given length. With T-square



23.240.1D
Figure 4-16.—Equilateral triangle on given inscribed circle: another method.

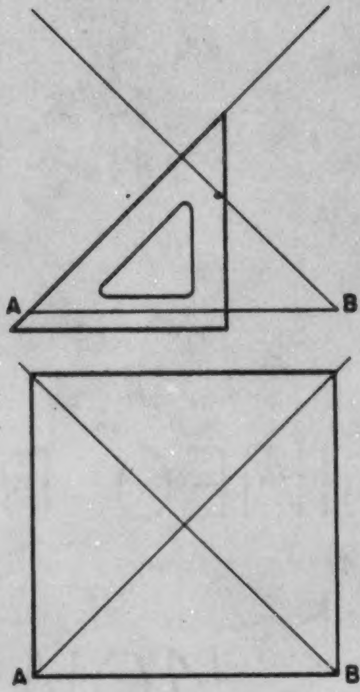
triangle erect perpendiculars from A and B, each equal to the given width. Connect the ends of the perpendiculars.

SQUARE: GIVEN LENGTH OF SIDE

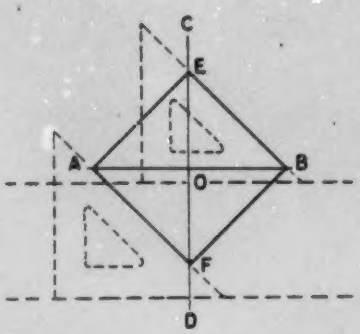
You can construct a square of given length of side by the method described for constructing a rectangle. Another method is illustrated in figure 4-17. Draw horizontal line AB with the T-square, equal to the given length of side. With the T-square and a 45° triangle, draw diagonals from A and B at 45° to AB. Erect perpendiculars from A and B, intersecting the diagonals, and connect the points of intersection.

SQUARE: GIVEN LENGTH OF DIAGONAL

Figure 4-18 shows a method of constructing a square with a given length of diagonal. Draw horizontal line AB, equal to given length of diagonal. Locate O at the center of AB, and lay off CD through O, perpendicular to and slightly longer than AB. Use T-square and 45° triangle to draw AF and EB at 45° to AB and CD. Connect AE and FB.



45.171
Figure 4-17.—Square with given length of side.



45.172
Figure 4-18.—Square with given length of diagonal.

SQUARE IN GIVEN CIRCUMSCRIBED CIRCLE

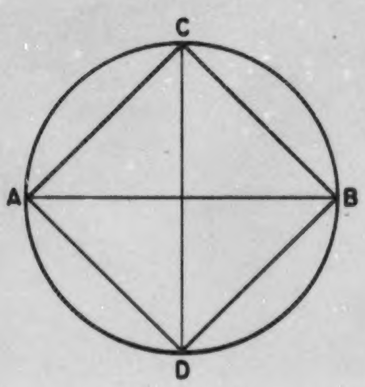
Figure 4-19 shows a method of drawing a square in a given circumscribed circle. Draw the diameters AB and CD at right angles to each other, and connect the points where the diameters intersect the circumference of the circle.

SQUARE CIRCUMSCRIBED ON GIVEN INSCRIBED CIRCLE

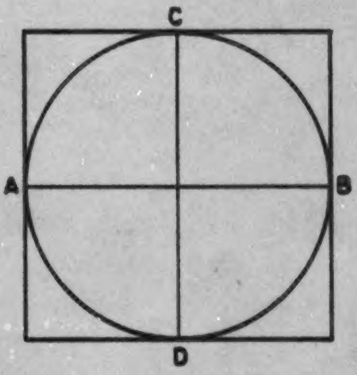
Figure 4-20 illustrates a method of circumscribing a square on a given inscribed circle. Draw the diameters AB and CD at right angles to each other. Then draw each side of the square tangent to the point where a diameter intersects the circumference of the circle, and perpendicular to the diameter.

ANY REGULAR POLYGON IN GIVEN CIRCUMSCRIBED CIRCLE

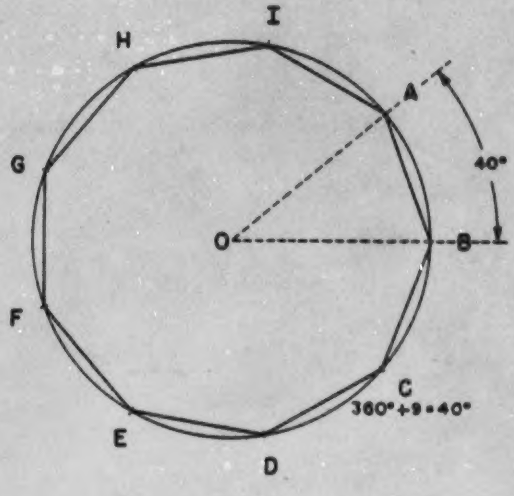
You can construct any regular polygon in a given circumscribed circle by trial-and-error with compass or dividers as shown in figure 4-21. To draw a 9-sided regular polygon in the circle shown, divide the circumference by trial-and-error with compass or dividers into 9 equal segments, and connect the points of intersection. To get a trial spread for the compass or dividers, divide the central angle subtended by the entire circle (360°) by the number of sides of the polygon (in this case, by 9). Then, lay off the central angle quotient from the center of the circle to the circumference with a protractor.



45.173
Figure 4-19.—Square in given circumscribed circle.



45.174
Figure 4-20.—Square on given inscribed circle.



45.175
Figure 4-21.—Regular polygon in given circumscribed circle.

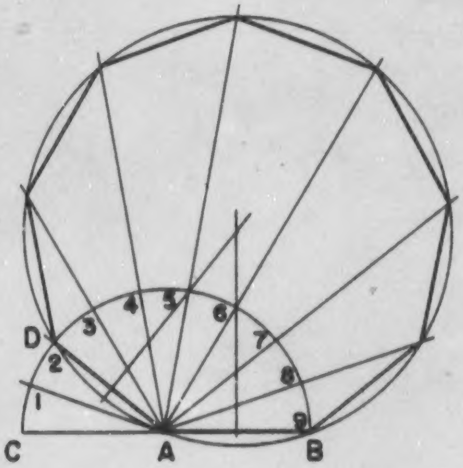
ANY REGULAR POLYGON ON GIVEN INSCRIBED CIRCLE

The same method (dividing the circumference into equal segments) can be used to construct a regular polygon on a given inscribed circle. In this case, however, instead of connecting the points of intersection on the circumference, you draw each side tangent to the circumference at perpendicular to the radius at each point of intersection, as shown in figure 4-22.

ANY REGULAR POLYGON WITH GIVEN LENGTH OF SIDE

Figure 4-23 illustrates a method of drawing any regular polygon with a given length of side. To draw a 9-sided regular polygon with length of side equal to AB, first extend AB to C, making CA equal to AB. With A as a center and AB (or CA) as a radius, draw a semicircle as shown. Divide the semicircle into 9 equal segments from C to B, and draw radii from A to the points of intersection. The radius A2 is always the second side of the polygon.

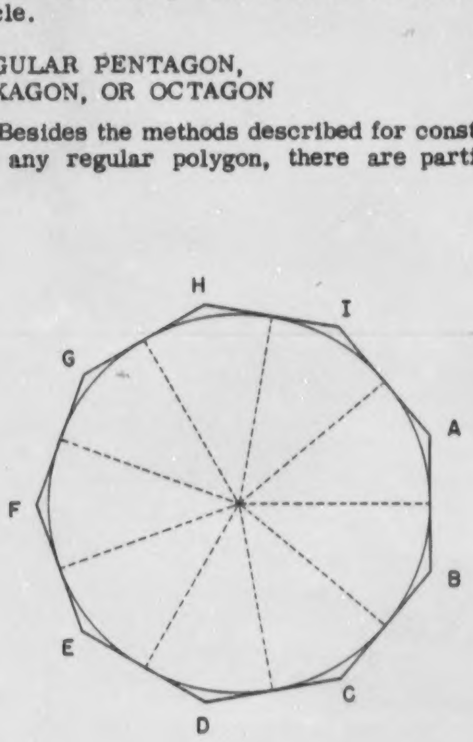
Draw a circle through points A, B, and D. To do this, first erect perpendicular bisectors from DA and AB. The point of intersection of the bisectors is the center of the circle. The circle is the circumscribed circle of the polygon. To draw the remaining sides, extend the radii from the semicircle as shown, and connect the points where they intersect the circumscribed circle.



45.176
Figure 4-23.—Any regular polygon with given length of side.

REGULAR PENTAGON, HEXAGON, OR OCTAGON

Besides the methods described for constructing any regular polygon, there are particular methods for constructing a regular pentagon, hexagon, or octagon.



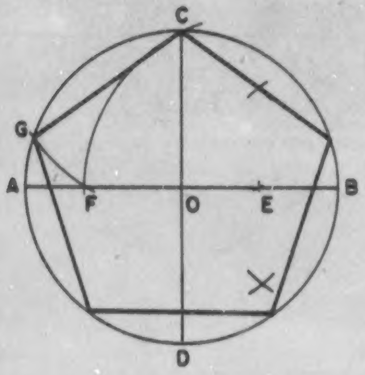
45.681
Figure 4-22.—Regular polygon on given inscribed circle.

Regular Pentagon in Given Circumscribed Circle

Figure 4-24 illustrates a method of constructing a regular pentagon in a given circumscribed circle. Draw a horizontal diameter AB and a vertical diameter CD. Locate E, the midpoint of the radius OB. Set a compass to the spread between E and C, and with E as a center strike the arc CF. Set the compass to the spread between C and F, and with C as a center strike the arc GF. A line from G to C forms one side of the pentagon. Set a compass to GC and lay off this interval from C around the circle. Connect the points of intersection.

Regular Pentagon on Given Inscribed Circle

To construct a regular pentagon on a given inscribed circle, determine the 5 equal intervals on the circle in the same manner. However, instead of connecting these points, draw each side of the figure tangent to the circle at a point of intersection.



45.177
Figure 4-24.—Regular pentagon in given circumscribed circle.

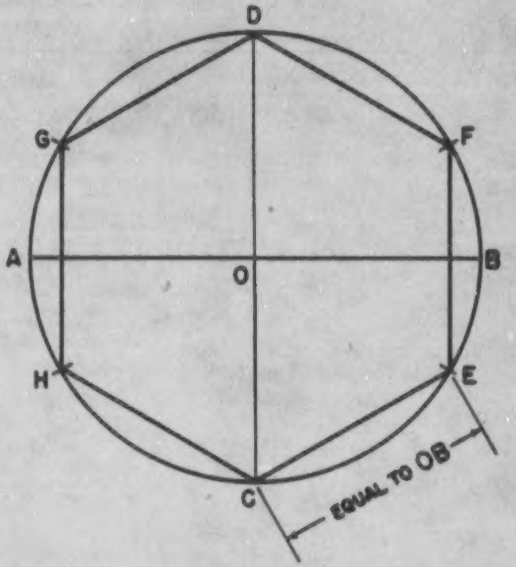
Regular Hexagon in Given Circumscribed Circle

Many bolt heads and nuts are hexagonal (6-sided) in shape. Figure 4-25 shows a method of constructing a regular hexagon in a given circumscribed circle. The diameter of the circumscribed circle has the same length as the long diameter of the hexagon. The radius of the circumscribed circle (which equals one-half the long diameter of the hexagon) is equal in length to the length of a side. Lay off the horizontal diameter AB and vertical diameter CD. OB is the radius of the circle. From C, draw a line CE equals to OB; then lay off this interval around the circle, and connect the points of intersection.

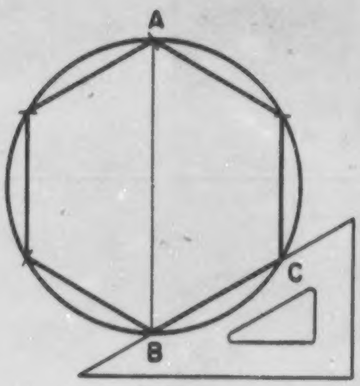
Figure 4-26 shows another method of constructing a regular hexagon in a given circumscribed circle. Draw vertical diameter AB, and use T-square and 30-60° triangle to draw BC from B at 30° to the horizontal. Set a compass to BC, lay off this interval around the circumference, and connect the points of intersection.

Regular Hexagon on Given Inscribed Circle

Figure 4-27 shows a method of constructing a regular hexagon on a given inscribed circle. Draw horizontal diameter AB and vertical centerline. Draw lines tangent to the circle and perpendicular to AB at A and B. Use T-square and 30-60° triangle to draw remaining sides of the figure tangent to the circle and at 30° to the horizontal.



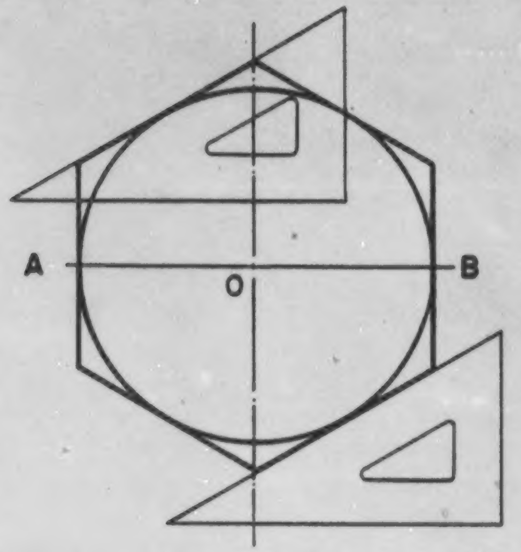
45.178
Figure 4-25.—Regular hexagon in given circumscribed circle: one method.



45.179
Figure 4-26.—Regular hexagon in given circumscribed circle: another method.

Regular Octagon in Given Circumscribed Circle

Figure 4-28 shows a method of constructing a regular octagon in a given circumscribed circle. Draw horizontal diameter AB and vertical



45.180
Figure 4-27.—Regular hexagon on given inscribed circle.

diameter CD. Use T-square and 45° triangle to draw additional diameters EF and GH at 45° to the horizontal. Connect the points where the diameters intersect the circle.

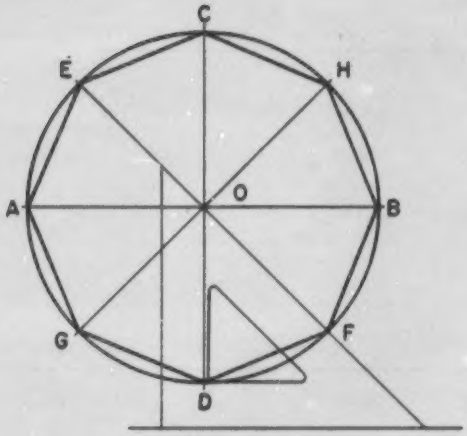
Regular Octagon on Given Inscribed Circle

Figure 4-29 shows a method of constructing a regular octagon around a given inscribed circle. Draw horizontal diameter AB and vertical diameter CD. Draw tangents at A, B, C, and D perpendicular to the diameters. Then use a T-square and 45° triangle to draw tangents at 45° to the horizontal, intersecting the first tangents drawn.

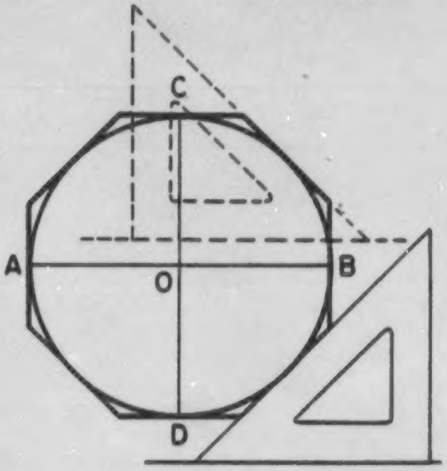
PENTACLE (STAR)

Figure 4-30 shows a method of constructing a pentacle. First draw (lightly) a horizontal line that is approximately greater than the diameter of the circle that could circumscribe the proposed star. With a compass, lay off the desired radius OG. Using OG as the radius, and point O as a center, draw the circle lightly. The circle intersects the horizontal line at H. HOG is now the diameter of the circle.

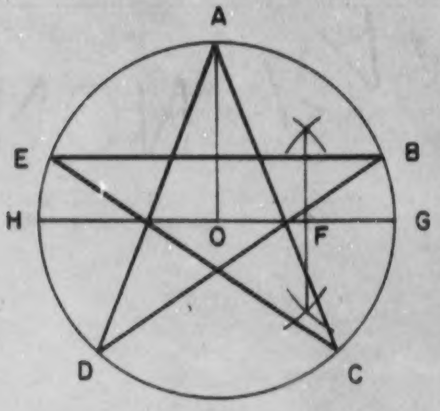
From O, erect (lightly) a perpendicular intersecting the circle at point A. Bisect the radius OG by any method, thereby creating point F.



45.181
Figure 4-28.—Regular octagon in given circumscribed circle.



45.182
Figure 4-29.—Regular octagon on given inscribed circle.



45.715
Figure 4-30.—Pentacle (star).

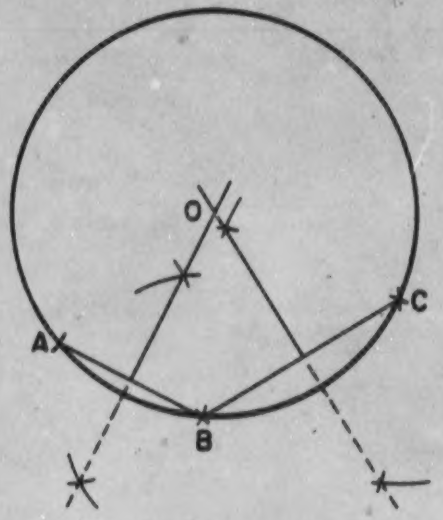
With a compass, measure off the distance AF. Using AF as the radius, and point A as a center, lay off thick marks at points E and B on the circle as shown. Likewise, using the same radius, AF, but this time using E and B as centers, mark off points D and C, respectively. Then connect AC, AD, BD, EC and EB with heavy lines—thus forming the pentacle (star).

CONSTRUCTION OF CURVES

Many of the common geometrical constructions occurring in the drafting room are those involving circular curves. In this section, we will explain how to construct circular curves that may be required to satisfy varying conditions.

CIRCLE THROUGH THREE POINTS

In figure 4-31 the problem is to draw a circle (or a circular arc) which passes through points A, B, and C. Connect the points by lines and erect perpendicular bisectors as shown. The point of intersection of the perpendicular bisectors is the center of the circle or arc passing through all three points.



45.183
Figure 4-31.—Circle or arc through three points.

LINE TANGENT TO A CIRCLE AT A GIVEN POINT

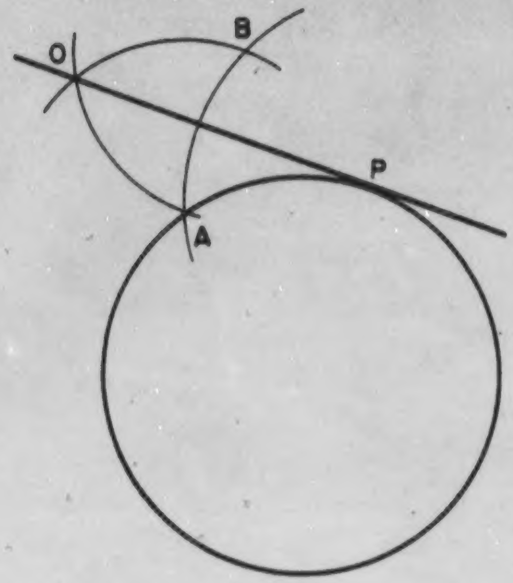
A line which is tangent to a circle at a given point is perpendicular to the radius which intersects the point. It follows that one method of drawing a line tangent to a circle at a given point is to draw the radius which interse the point, and then draw the line tangent at the point of intersection and perpendicular to the radius.

Another method is shown in figure 4-32. To draw a line tangent to the circle at P, set a compass to the radius of the circle and, with P as a center, strike an arc which intersects the circle at A. With the compass still set to the radius of the circle, use A as a center and strike an arc which intersects the first arc at B. With B as a center and the compass still set to the radius of the circle, strike another arc. A line through the point of intersection of the last-drawn arc and through P is tangent to the circle at P.

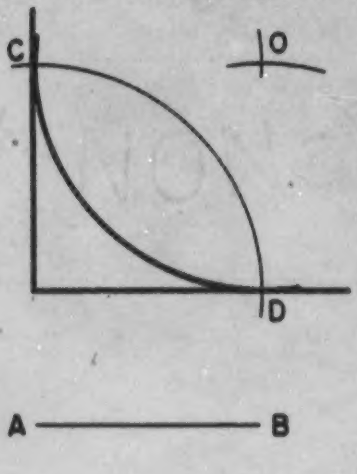
CIRCULAR ARC OF GIVEN RADIUS TANGENT TO TWO STRAIGHT LINES

The problem of drawing a fillet or round (explained in a previous section) comprises the problem of drawing a circular arc of given radius tangent to two non-parallel lines.

Figure 4-33 shows a method which can be used when the two nonparallel lines form a right angle. AB is the given radius of the arc. Set a compass to this radius, and with the point of intersection of the lines as a center, st



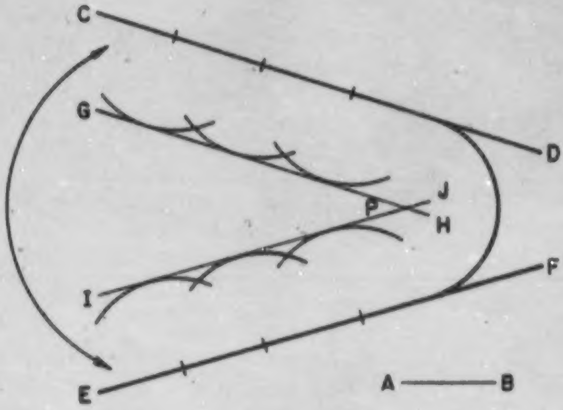
45.184
Figure 4-32.—Line tangent to given point on circle.



45.185
Figure 4-33.—Circular arc tangent to two lines which form a right angle.

an arc intersecting the lines at C and D. With C and D as centers and the same radius, strike intersecting arcs as shown. The point of intersection of these arcs is the center of the circle of which an arc of the given radius is tangent to the lines.

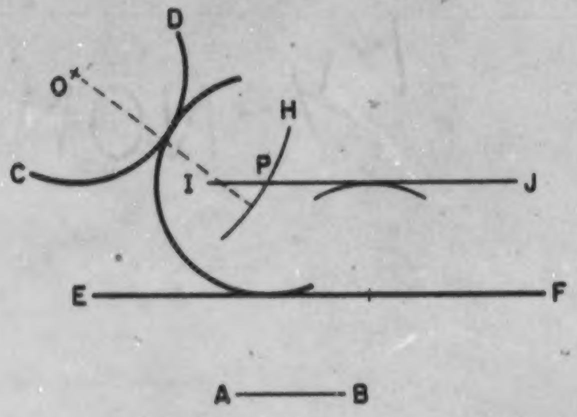
Figure 4-34 shows a method which can be used regardless of the size of the angle formed by the lines. Again AB equals the given radius of the arc, and the problem is to draw an arc with radius equal to AB, tangent to CD and EF. Draw GH parallel to CD, and at a distance from CD equal to the given radius of the arc. Draw IJ parallel to EF, also at a distance equal to the given radius of the arc. The point of intersection between GH and IJ is the center of the circle of which an arc of the given radius is tangent to CD and EF.



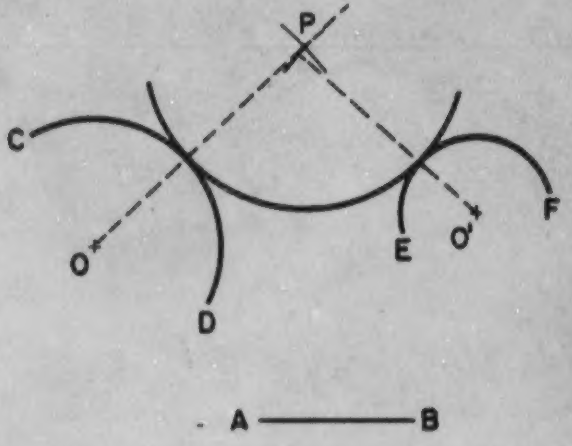
45.186
Figure 4-34.—Circular arc tangent to two lines which form any angle.

CIRCULAR ARC OF GIVEN RADIUS TANGENT TO STRAIGHT LINE AND TO ANOTHER CIRCULAR ARC

The problem in figure 4-35 is to draw a circular arc with radius equal to AB, tangent to the circular arc CD and to the straight line EF. Set a compass to a radius equal to the radius of the circular arc CD plus the given radius AB (which is indicated by the dotted line shown), and with O as a center strike the arc GH. Draw a line IJ parallel to EF, at a distance from EF equal to AB. The point of intersection between GH and IJ is the center of the circle of which an arc of the given radius is tangent to CD and EF.



45.187
Figure 4-35.—Circular arc tangent to a straight line and another circular arc.



23.235
Figure 4-36.—Circular arc tangent to two other circular arcs.

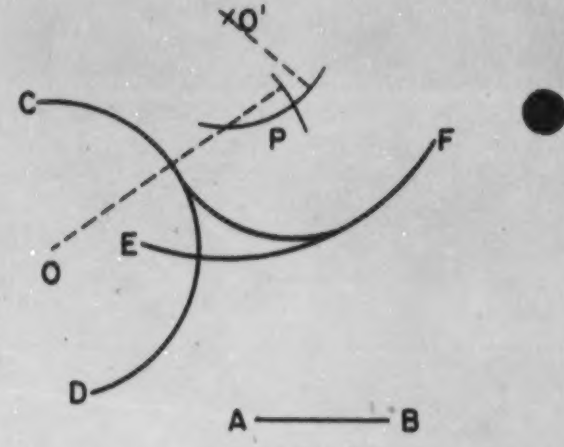
CIRCULAR ARC OF GIVEN RADIUS TANGENT TO TWO OTHER CIRCULAR ARCS

The problem in figure 4-36 is to draw an arc with radius equal to AB, tangent to the circular arcs CD and EF. Set a compass to a spread equal to the radius of CD plus AB (indicated by the left-hand dotted line), and with O as a center strike an arc. Set the compass to a spread equal to the radius of EF plus AB (indicated by the right-hand dotted line), and with O' as a center strike an intersecting arc. The point of intersection between the two arcs is the center of the circle of which an arc of given radius is tangent to CD and EF.

In figure 4-36, the circular arcs CD and EF curve in opposite directions. In figure 4-37, the problem is to draw an arc with radius equal to AB, tangent to two circular arcs, CD and EF, which curve in the same direction.

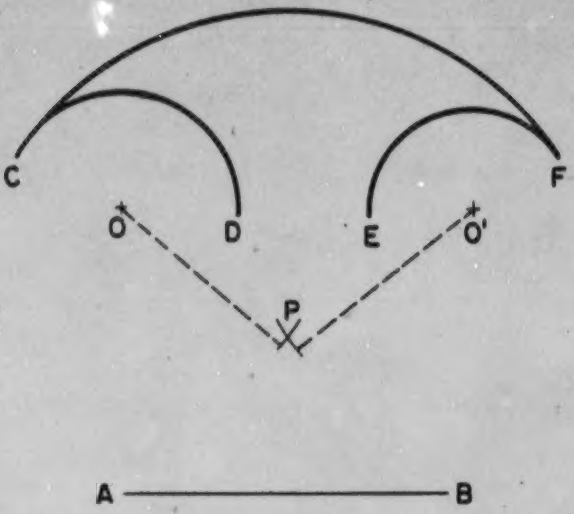
Set compass to a radius equal to the radius of EF LESS AB, and with O' as a center strike an arc. Then, set the compass to a radius equal to the radius of arc CD plus line AB, and O as center strike an intersecting arc at P. The point of intersection between these two arcs is the center of the circle of which an arc of the given radius is tangent to CD and EF.

When a circular arc is tangent to another, it is commonly the case that the two arcs curve in opposite directions. However, an arc may be drawn tangent to another with both curving in the same direction. In a case of this kind, the tangent arc is said to "enclose" the other.



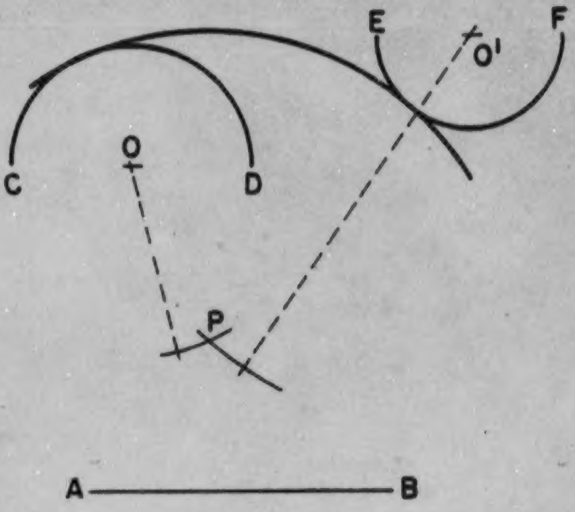
45.189
Figure 4-37.—Circular arc tangent to arcs which curve in the same direction.

An arc tangent to two others may enclose both, or it may enclose only one and not the other. In figure 4-38, the problem is to draw a circular arc with radius equal to AB, tangent to and enclosing both CD and EF. Set a compass to a radius equal to AB less the radius of CD (indicated by the dotted line from O), and with O as a center strike an arc. Set the compass



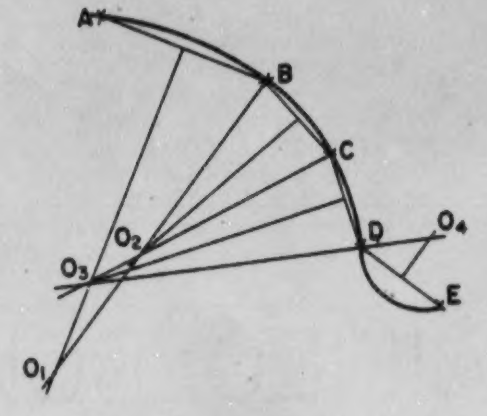
45.190

Figure 4-38.—Circular arc tangent to and enclosing two other circular arcs.



45.191

Figure 4-39.—Circular arc tangent to and enclosing one arc, and tangent to but not enclosing another.



45.192

Figure 4-40.—Curve composed of a series of consecutive tangent circular arcs.

a radius equal to AB less the radius of EF (indicated by the dotted line from O'), and with O' as a center strike an intersecting arc at P. The point of intersection between these two arcs is the center of a circle of which an arc of given radius is tangent to, and encloses, both CD and EF.

In figure 4-39, the problem is to draw a circular arc with radius equal to AB, tangent to and enclosing CD, and tangent to but NOT enclosing EF. Set a compass to a radius equal to AB less the radius of CD (indicated by the dotted line from O), and with O as a center strike an arc. Set the compass to AB PLUS the radius of EF (as indicated by the dotted line from O'), and with O' as a center strike an intersecting arc at P. The point of intersection between the two arcs is the center of a circle of which an arc of the given radius is tangent to and encloses CD, and also tangent to, but does not enclose, EF.

COMPOUND CURVE

A curve which is made up of a series of successive tangent circular arcs is called a "compound" curve. In figure 4-40, the problem is to construct a compound curve passing through given points A, B, C, D, and E. First connect the points by straight lines. The straight line between each pair of points constitutes the chord of the arc through the points.

Erect a perpendicular bisector from AB. Select an appropriate point O_1 on the bisector as a center, and draw the arc AB. From O_1 draw the radius O_1B. From BC erect a perpendicular bisector. The point of intersection

O_2 between this bisector and the radius O_1B is the center for the arc BC. Draw the radius O_2C, and erect a perpendicular bisector from CD. The point of intersection O_3 between this bisector and the extension of O_2C is the center for the arc CD.

To continue the curve from D to E you must reverse the direction of curvature. Draw the radius O_3D, and erect a perpendicular bisector from DE on the opposite side of the curve from those previously erected. The point of intersection between this bisector and the extension of O_3D is the center of the arc DE.

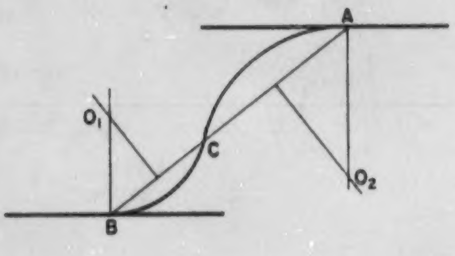
REVERSE OR OGEE CURVE

A "reverse" or "ogee" curve is composed of two consecutive tangent circular arcs which curve in opposite directions.

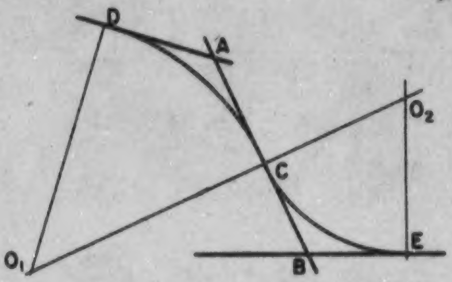
Figure 4-41 shows a method of connecting two parallel lines by a reverse curve tangent to the lines. The problem is to construct a reverse curve tangent to the upper line at A and to the lower line at B.

Connect A and B by straight line AB. Select on AB point C where you want to have the reverse curve change direction. Erect perpendicular bisectors from BC and CA, and erect perpendiculars from B and A. The points of intersection between the perpendiculars (O_1 and O_2) are the centers for the arcs BC and CA.

Figure 4-42 shows a method of constructing a reverse curve tangent to three intersecting straight lines. The problem is to draw a reverse curve tangent to the three lines which intersect at points A and B. Select on AB point C where you want the reverse curve to change direction. Lay off from A a distance equal to AC to establish point D. Erect a perpendicular from D and another from C. The point of intersection of these perpendiculars (O_1) is the center of the arc DC.



45.193
Figure 4-41.—Reverse curve connecting and tangent to two parallel lines.



45.194
Figure 4-42.—Reverse curve tangent to three intersecting straight lines.

Lay off from B a distance equal to CB to establish point E. Erect a perpendicular from E, and extend O_1C to intersect it. The point of intersection (O_2) is the center of the arc CE.

RECTIFYING A CIRCULAR ARC

One of the meanings of the word "rectify" is: "to straighten." To "rectify" a circular arc means to straighten it out—that is, to draw [illegible] straight line having the same length as the length of the arc.

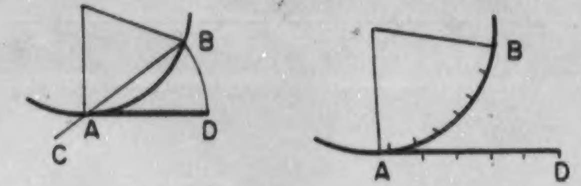
In figure 4-43, the problem is to rectify the arc AB. From A draw line AD tangent to arc AB, with chord BA extended. Lay off AC equal to one-half of AB. With C as center and CB as radius, draw an arc intersecting AD at D. AD will be slightly shorter than the length of arc AB.

If the central angle of the given arc is between 45° and 90°, a closer approximation will result by making AC equal to the chord of half the arc instead of half the chord of the arc.

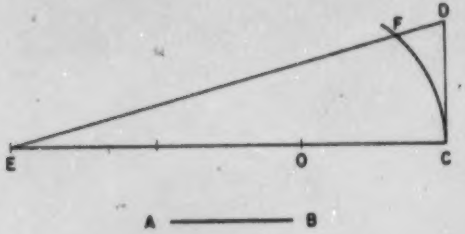
The usual procedure for rectifying an arc is to set the dividers into a space small enough to be practically equal in length to the corresponding arc. Starting at B in figure 4-43 and without lifting the dividers, step along the arc noting the number of steps and fraction thereof; then, step off the same number of spaces on the tangent as shown in the illustration.

LAYING OFF A GIVEN LENGTH ON A CIRCULAR ARC

Figure 4-44 shows a method of laying off a given length on a circular arc. The problem [illegible] to lay off, on the arc shown, a length equal



45.195(45B)
Figure 4-43.—Rectifying a circular arc.



45.196
Figure 4-44.—Laying off a given length on a circular arc.

AB. Draw the radius OC, and draw tangent CD equal to AB and perpendicular to OC. Extend CO to E, making OE twice as long as OC. Connect E and D by a straight line intersecting the arc at F. The arc FC is very slightly shorter than the tangent CD—that is, very slightly shorter than the given length AB. For a central angle of 30° the difference would be 1 in 2326; for a central angle of 45° it would be 1 in 420; for a central angle of 60° it would be 1 in 132.

This method can also be used for rectifying a circular arc. It is slightly less accurate than the method previously described.

CONSTRUCTIONS INVOLVING NONCIRCULAR CURVES

The basic uniform noncircular curves are the ellipse, the parabola, and the hyperbola. These curves are derived from conic sections as shown in figure 4-45. The circle itself (not shown, but a curve formed by a plane passed through a cone perpendicular to the vertical axis) is also derived from a conic section.

ELLIPSE BY PIN-AND-STRING METHOD

The dimensions of an ellipse are given in terms of the lengths of the major (longer) and minor (shorter) axes. Figure 4-46 shows a method of constructing an ellipse which is called the "pin-and-string" method. The problem is to construct an ellipse with major axis AB and minor axis CD. Set a compass to one-half the length of AB, and with C as a center strike arcs intersecting AB at F and F'. Set a pin at point C, another at F, and a third at F'. Tie the end of a piece of string to the pin at F, pass the string around the pin at C, draw it taut, and fasten to the pin at F'. Remove the pin at C, place the pencil point in the bight of the string, and draw the ellipse as shown in view C, keeping the string taut all the way around.

ELLIPSE BY TRAMMEL METHOD

Another method of constructing an ellipse, called the "trammel" method, is shown in figure 4-47. In this method, you plot a series of points along the ellipse by the use of a marked straightedge called a trammel. A strip of paper, cardboard, or plastic, or the edge of a triangle, will serve the purpose.

On the edge of the trammel, lay off OE equal to one-half the minor axis CD and OF equal to one-half the major axis AB. If the trammel is set on the axes so that E is constantly on the major axis AB and F constantly on the minor axis CD, O will lie always on the ellipse for any angle of the trammel. Figure 4-47 shows how you can apply this fact to plot a series of points along the ellipse. You can then fair a line through the points with a french curve.

ELLIPSE BY FOCI METHOD

A third method of constructing an ellipse, called the "foci" method, is shown in figure 4-48. In this method you plot a series of points along the ellipse by drawing a series of intersecting arcs, using points F and F' on the major axis (these points are the "foci") as centers.

To locate the foci, set a compass to one-half of the major axis and, with C as a center, strike arcs intersecting the major axis at F and F'. Divide OF into at least 5 equal intervals (there are 6 in figure 4-48). To plot the first pair of intersecting arcs, set the compass to A1 and,

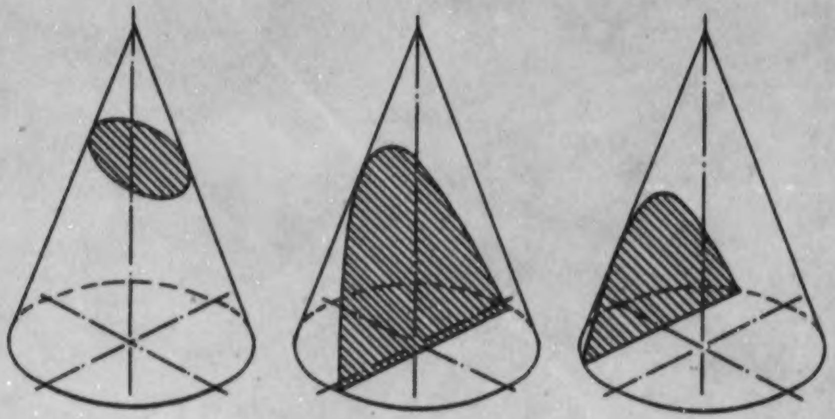


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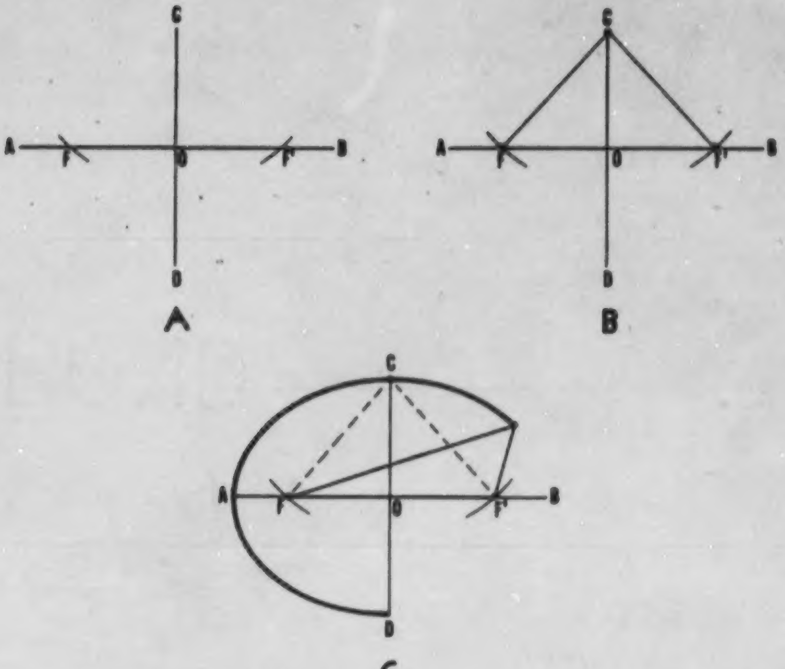
Figure 4-45.—Conic sections: (A) ellipse; (B) parabola; (C) hyperbola.


C
A
F
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F'
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D
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Figure 4-46.—Ellipse by pin-and-string method.

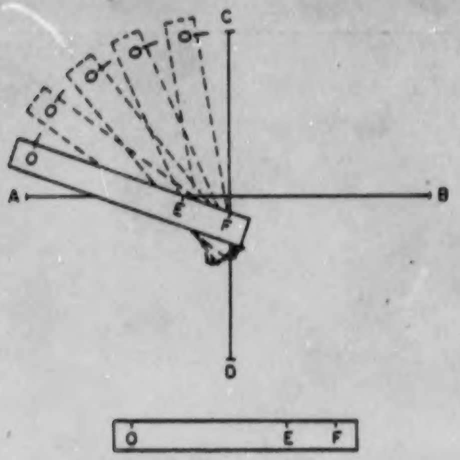

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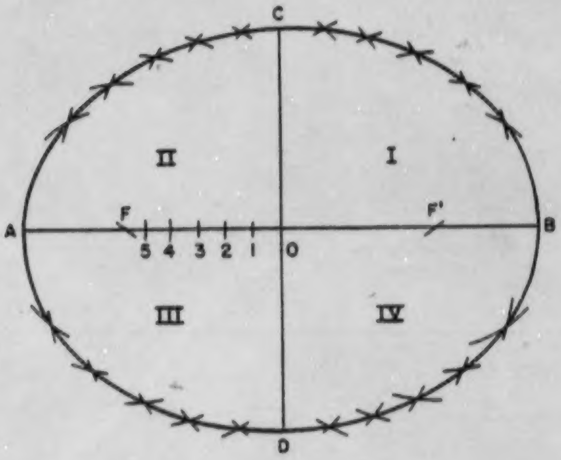
Figure 4-47.—Ellipse by trammel method.



45.200
Figure 4-48.—Ellipse by foci method.

with F' as a center, strike an arc in I and IV quadrants; then set the compass to B1 and, with F as a center, strike an intersecting arc. To plot the next pair, set the compass to A2 and, with F' as a center, strike an arc in I and IV quadrants; then set the compass to B2 and, with F as a center, strike an intersecting arc. Continue in this fashion to plot the points between the first quadrant and the fourth quadrant. To plot the points between the second and the third quadrants, proceed in the same manner. Next, fair a line through the points with a french curve.

ELLIPSE BY CONCENTRIC CIRCLE METHOD

Figure 4-49 shows the "concentric circle" method of drawing an ellipse. With the point of intersection between the axes as a center, draw two concentric circles (circles with a common center), one with diameter equal to the major axis and the other with diameter equal to the minor axis, as shown in figure 4-49(A). Draw a number of diameters as shown in 4-49(B). From the point of intersection of each diameter with the larger circle draw a vertical line; and from the point of intersection of each diameter with the smaller circle draw an intersecting horizontal line, as shown in 4-49(C). Draw the ellipse through the points of intersection, as shown in 4-49(D).

ELLIPSE ON GIVEN CONJUGATE DIAMETERS

The major and minor axes of an ellipse are perpendicular to each other. "Conjugate" diameters of an ellipse are diameters which are not perpendicular to each other. Figure 4-50 shows a method of constructing an ellipse on given

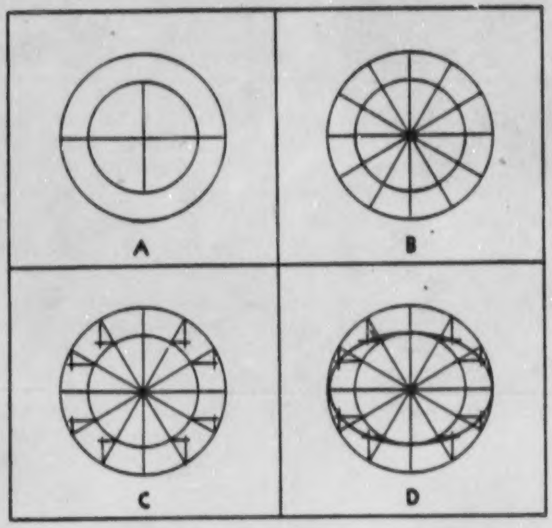


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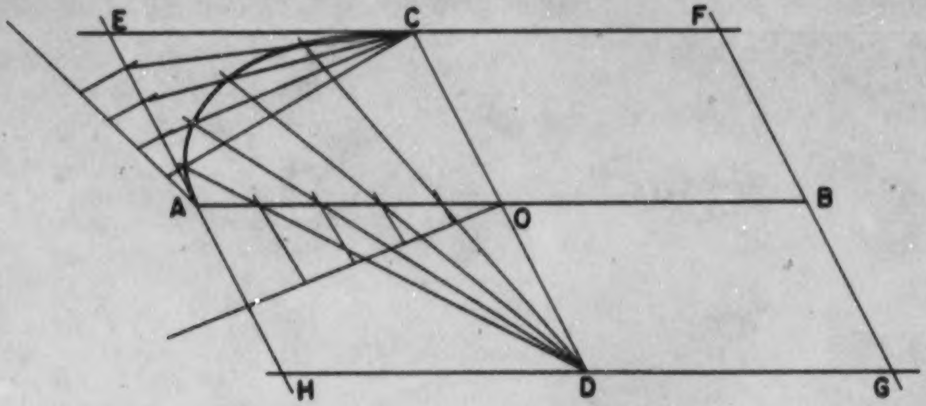
Figure 4-49.—Ellipse by concentric circle method.



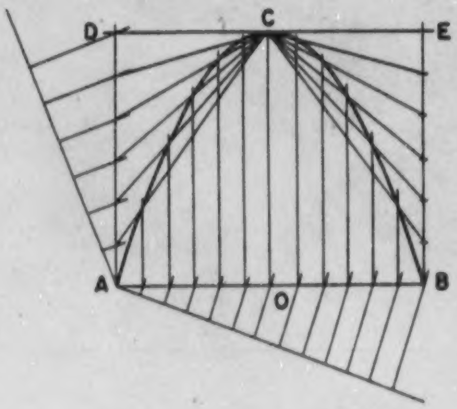
45.202
Figure 4-50. — Ellipse on given conjugate diameters.

conjugate diameters. First draw the circumscribing parallelogram EFGH. Divide EA and AO into the same number of equal intervals. Draw lines from D through the intervals of AO, and lines from C to the intervals of EA. Draw the ellipse through the points of intersection of these lines. For the other three-quarters of the ellipse, proceed in the same fashion with the other three-quarters of the parallelogram.

PARABOLA

Figure 4-51 shows a method of drawing a parabola. The problem is to draw a parabola which starts at A, ends at B, and has CO as a vertical axis. Draw AD, DE, and EB, creating the rectangle ADEB. Divide AD and BE into a number of equal intervals, and divide AB into twice as many equal intervals. Draw lines from C to the intervals along AD and BE, and erect perpendiculars from the intervals of AB to intersect these lines. Draw the parabola through the points of intersection as shown.

This method is a general method which can be used to construct any curve derived from a conic section. Figure 4-52 shows its use in constructing an ellipse with major axis AB and minor axis CD. Figure 4-50 shows its use in constructing an ellipse on given conjugate axes.



45.203
Figure 4-51. — Parabola.

HYPERBOLA

Figure 4-53 shows the use of the general method to construct a hyperbola. The problem here is to draw a hyperbola which starts at A, ends at B, and has CO as a vertical axis. Draw AD, DF, and EB, creating the rectangle ADEB. Divide AD and BE into a number of equal intervals, and divide AB into twice as many equal intervals. Extend OC to C'. The amount you extend it depends on how sharp you want the curve of the hyperbola to be. The longer you make C'O, the flatter the curve will be.

Draw lines from C to the intervals along AD and BE, and lines from C' to the intervals of AB. Draw the hyperbola through the points of intersection as shown.

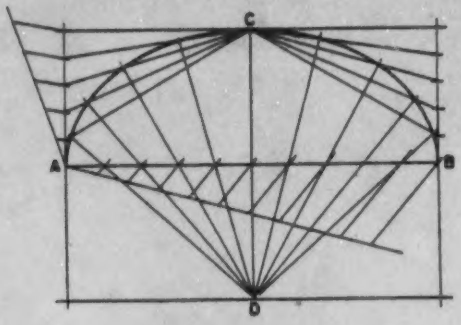


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Figure 4-52.—Ellipse by general method for drawing any curve derived from a conic section.

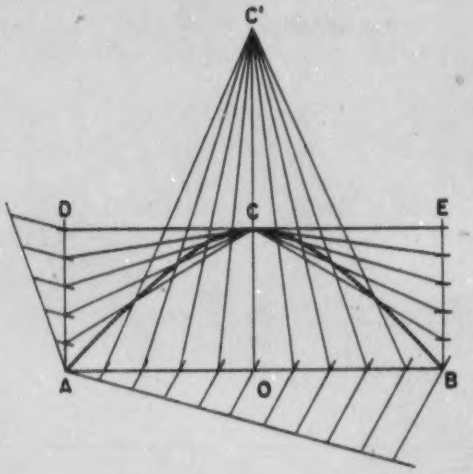

Figure 4-53.—Hyperbola. 45.205

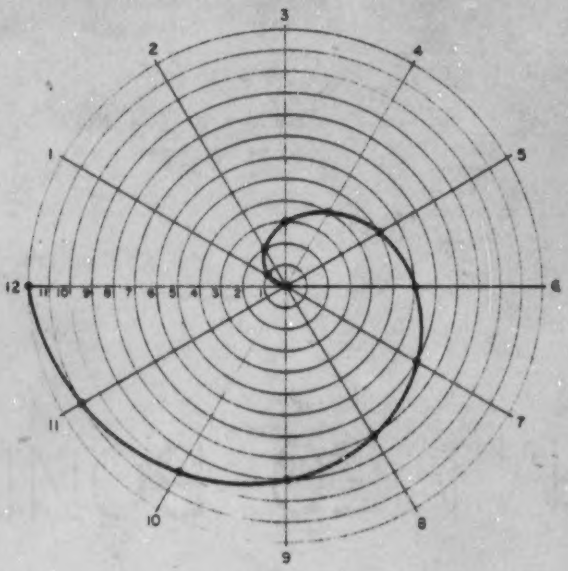

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Figure 4-54.—Spiral of Archimedes.

SPIRAL OF ARCHIMEDES

A "spiral of Archimedes" is a curve which follows the path which would be traced by a point moving around and away from a fixed point (called the "pole") in such a manner as to have the distance of the point from the pole increase uniformly with the angle generated by the point.

The method of constructing a spiral of Archimedes is based on this definition. In figure 4-54, the problem is to construct a spiral of Archimedes beginning at the pole O. Draw a succession of lines from O, with equal angles between the lines (an angle of 30° is suitable). Divide one of the lines into 12 equal intervals. Then, from pole O, draw 12 concentric circles as shown in figure 4-54, and number them consecutively from the center. Next, plot a point where line 1 and circle 1 intersect, as illustrated. Continue plotting in the same manner up to line 12 and circle 12, and fair a line through these points with a french curve.

CHAPTER 5

DRAFTING: PROJECTIONS, REPRODUCTIONS, AND FILING

This chapter covers various methods of projection and engineering drawing techniques. It discusses conventional methods used in presenting different views of a drawn object, so that the drawing conveys all information necessary for construction or manufacture of the object. It also discusses various drawing reproduction processes and methods of filing drawings.

THEORY OF PROJECTION

A technical drawing of an object is an accurate graphic representation of the object, drawn on a plane surface. The representation is made by projecting the points and lines of the object onto the plane surface. The plane surface, often called the PLANE of PROJECTION or PICTURE PLANE, is always placed between the observer and the object to be projected.

Projection is done, in theory, by extending lines of sight, called PROJECTORS, from the eye of the observer through lines and points on the object to the plane of projection.

CENTRAL PROJECTION

If the line of sight were literally followed, the result would be the type of projection illustrated in figure 5-1. Because the projectors converge at a single central point (the eye of the observer), this type is called CENTRAL projection.

You can see that the projected view of the object varies considerably in size, according to the relative positions of the object, the plane of projection, and the eye of the observer. For this and other reasons, central projection is seldom used for the projection of technical drawings.

PARALLEL PROJECTION

If the observer were located an infinite distance away from the object and its plane of projection, the projectors, instead of converging to a point, would be parallel to each other. For reasons of convenience, this is presumed to be the case for most technical drawings. Figure 5-2 illustrates parallel projection. You can see that, if the projectors are perpendicular to the plane of projection (as they are in figure 5-2), the dimensions of the projection are the same as the dimensions of the object, regardless of the relative positions and distances.

ORTHOGRAPHIC AND OBLIQUE PROJECTION

An ORTHOGRAPHIC projection is a parallel projection in which the projectors are perpendicular to the plane of projection. An OBLIQUE

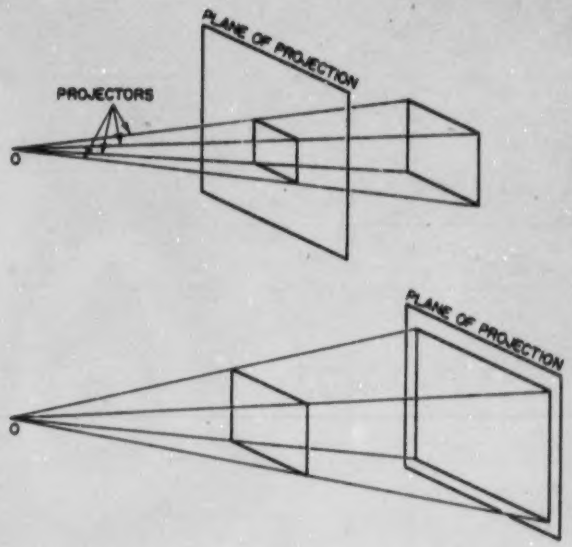

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Figure 5-1.—Central projection.

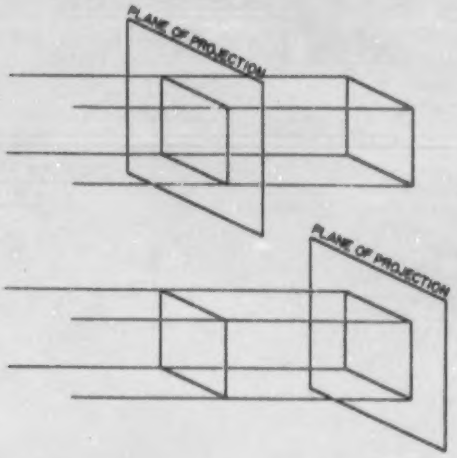

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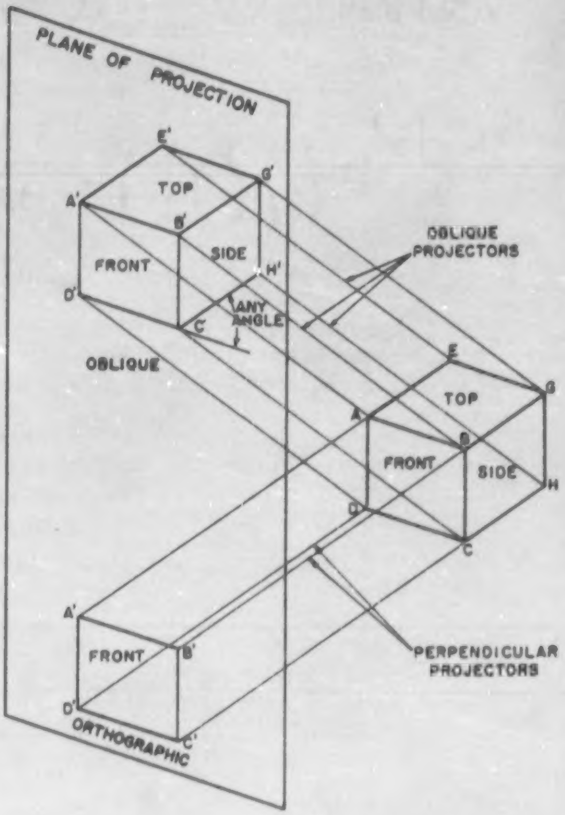
Figure 5-2.—Parallel projection.

projection is a parallel projection in which the projectors are oblique (not perpendicular) to the plane of projection.

Figure 5-3 shows the same object by both orthographic and oblique projections. Always imagine that the plane of projection is between the observer and the object. In figure 5-3 the block is placed in such a manner that its front surface (the surface toward the plane of projection and represented by ABCD) is parallel to the plane of projection.

As you can see, the resulting image in the orthographic projection shows only the front surface of the block, as indicated by A'B'C'D'; it shows only two dimensions—the height and the width, which are both true dimensions.

On the other hand, the oblique projection (as shown in the upper image of figure 5-3) shows the front, the side and the top surfaces. By so doing, it shows three dimensions—the width, the length, and the height. If you examine figure 5-3 closely, you will observe that the primed letters on the plane of projection correspond to the letters on the block. It should be noted, however, that the front face of the block is seen in its true size and shape in both images. Notice also that hidden lines are not generally shown in the projection. Oblique projection is one method by which an object can be shown in a single view and in all three dimensions. It is the simplest type of pictorial drawing.



45.226(45B)
Figure 5-3.—Comparison between oblique and orthographic projection of a cube.

SINGLE-PLANE PROJECTION

A type of projection in which an object can be shown in all three dimensions in one picture plane is called a SINGLE-PLANE projection. The oblique projection shown in figure 5-3 is an example.

OBLIQUE SINGLE-PLANE PROJECTIONS

There are two common types of oblique single-plane projections: the cavalier projection and the cabinet projection.

Cavalier Projection

In a cavalier projection the projectors are presumed to make a 45° angle, both vertically and horizontally, with the plane of projection. Assume that in figure 5-4 the line XX' represents a side-edge view of the plane of projection, and that the square ABCD represents a side of a cube, placed with its front face parallel to and its top face perpendicular to the plane of projection. You can see that the projected lengths of AB and AC, as well as A'B' and A'C', are the same as their actual lengths, and the fact that they are the same can be proved geometrically.

Assume now that the line XX' represents a top-edge view of the plane of projection, and that the square ABCD represents the top of the cube. Again the projected lengths of AB and AC are the same as the actual lengths.

In a cavalier projection, then, any line which is parallel to, or perpendicular to, the plane of projection is projected in its true length. Such a line is called a "regular" line.

Figure 5-5 shows the comparison between a cavalier and a cabinet projection of the same cube shown in figure 5-4. You start by drawing the axes, which consist of the front axes OX and OY and the "receding" axis OZ. The front axes are perpendicular to each other; the receding axis OZ is drawn 45° with the horizontal axis OX, and this is true only for both cavalier and cabinet projections drawings. The receding lines of the cavalier and cabinet projections make 45° with the front axes; in oblique drawing, this could be any acute angle.

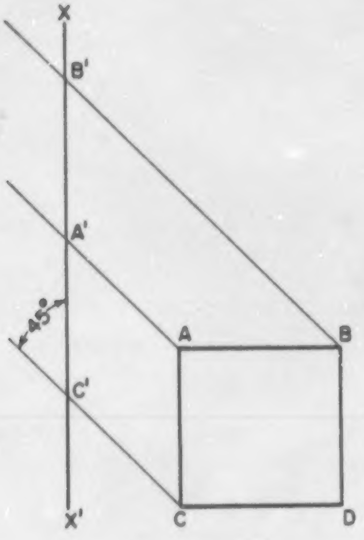


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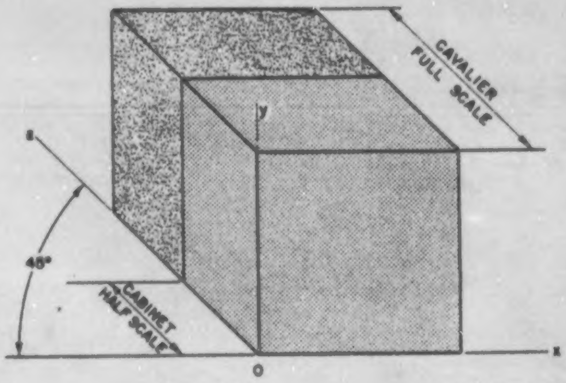
Figure 5-4.—Angle of projectors in cavalier projection.



45.228:.229
Figure 5-5.—Comparison between cavalier and cabinet projection of a cube.

After the axes are drawn, complete the projection by measuring off the dimensions of the respective faces of the object. In a cube, the dimensions are equal; however, in a cavalier projection the receding portion appears longer, because cavalier projection compensates for our natural human optical illusions. To our naked eyes, an object becomes smaller as its distance from us becomes greater. This optical illusion causes receding parallel lines to seem shorter than they really are. These lines also appear to converge toward a point in the distance, such as the image you will see when you stand at the center of a railroad track and gaze ahead in the direction of the rails to where they meet the horizon.

In a cavalier projection, receding parallel lines remain parallel and retain their true lengths. As shown in figure 5-5, the far edge of the cube appears equal in length to the corresponding front edge.

Cabinet Projection

Because the eye is accustomed to its illusions, a cavalier projection gives an appearance of distortion. This appearance is sometimes minimized by reducing the receding dimension as indicated in figure 5-5. The dimension along the receding axis can be reduced by any amount; when it is reduced by half, the resulting projection is called a cabinet drawing. As you can s the eye is better satisfied with this representation. However, this satisfaction is obtained by deliberately introducing an error in the representation, that is, by making the receding dimension along axis OZ only half as long as it actually is.

ORTHOGRAPHIC SINGLE-PLANE PROJECTION

In accordance with the theory of projection, the following types of projective systems are classified under orthographic single-plane projection:

1. Isometric projection
2. Isometric drawing
3. Dimetric projection
4. Trimetric projection

These projections are technically known as "axonometric" projection. Axonometric projection is a form of orthographic projection in that the projectors are always perpendicular to the plane of projection; that is, the object itself, rather than the projectors, is placed inclined to the picture plane.

Isometric Projection

An isometric projection is a single-plane projection which gives the appearance of "naturalness" without the introduction of any error. Isometric projection is orthographic projection—that is, the projectors are presumed to be perpendicular to the plane of projection. It is the object itself that is presumed to be inclined to the plane, as shown in figure 5-6. Here the cube is placed with a corner toward the plane of projection, and inclined so that each of its surfaces makes an angle of 35° 16' (called the isometric angle) with the plane.

The projection of each of the edges of the cube is slightly shorter than the actual length of the edge. The amount of reduction may be expressed as the ratio of 1 to the cosine of 35° 16'. The cosine of 35° 16' is 0.8165. Therefore, if the edge of the cube were 1 in. long, the projected edge would be 0.8165 in. long.

Any line on the object which makes the isometric angle with the plane of projection is called an isometric line. All isometric lines project in the same foreshortening ratio (1:0.8165); hence the term "isometric," which means "equal measure."

Figure 5-7 shows the isometric projection of figure 5-6 as it would look to an observer whose line of sight was perpendicular to the plane of projection. The figure is built on a central axis consisting of three axes—OA, OB, and OC—120° apart.

Isometric Drawing

Assume that the projection shown in figure 5-7 is that of a cube which has dimensions 1 in. x 1 in. x 1 in. For an isometric projection made full-scale, the dimensions would be 0.8165 in. x 0.8165 in. x 0.8165 in.

Now, if you made the drawing with dimensions the same as those of the object (1 in. x 1 in. x 1 in.), the drawn figure would be slightly larger than a true isometric projection, but there would be no significant difference otherwise. The proportions of the figure with respect to each other would be the same. Consequently, in practice it is

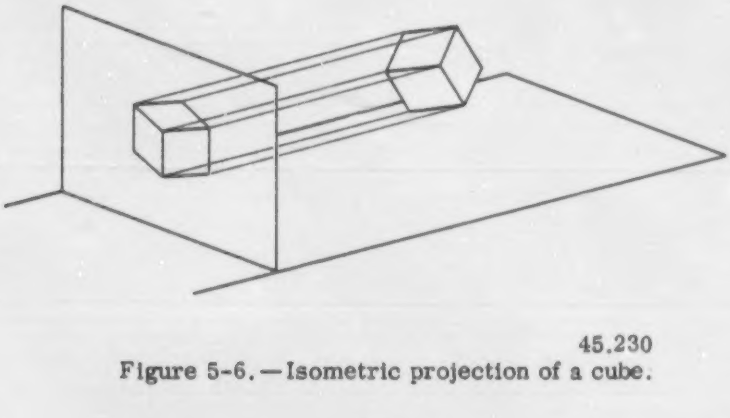


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Figure 5-6.—Isometric projection of a cube.

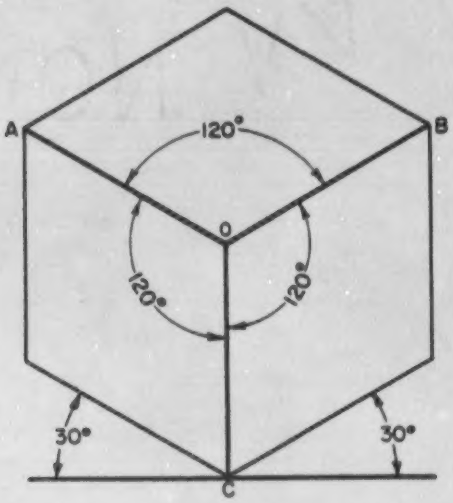

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Figure 5-7. —Isometric axis.

often the case that an isometric "drawing" rather than an isometric "projection" is made. In a full-scale isometric drawing the lengths of isometric lines are made the same as the lengths of the same lines on the object, instead of being scaled down in the ratio of 1:0.8165, as they are in a full-scale isometric projection.

It would be worthwhile to mention the significant differences between an isometric drawing and both orthographic and perspective drawings. The significant differences are as follows:

1. An isometric drawing generally shows three or more surfaces in a given view, whereas an othographic drawing only shows one surface.
2. In an isometric drawing, the receding lines remain parallel, whereas in a perspective drawing they converge. Perspective drawing is discussed later in this chapter.

Dimetric Projection

In an isometric projection of a cube, all of the surfaces of the cube make the same angle with the plane of projection. A cube has three pairs of opposing surfaces.

In a DIMETRIC projection of a cube, only two pairs of surfaces make the same angle with the plane of projection, while the third pair makes a different angle. Figure 5-8 shows a dimetric projection of a cube. The pairs of surfaces which form the sides make the same angle with the plane of projection. The pair which forms the top and bottom makes a different angle. It follows that the foreshortening of the dimensions of the side surfaces is not the same as that of the dimensions of the top and bottom surfaces. Therefore, two different scales are required for foreshortening; hence the term "dimetric," which means "two-measure."

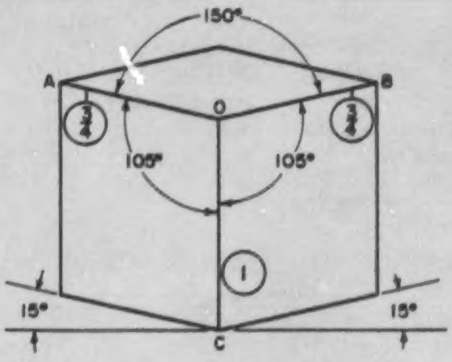

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Figure 5-8. —Dimetric projection of a cube, showing one practical dimetric axis.

An isometric projection is built on an axis consisting of three axes at 120° to each other. A dimetric projection is also built on a three-legged axis, but the angles between the legs are variable according to the angle of inclination of one pair of surfaces to the plane of projection.

There are three axes which have been found suitable for most dimetric projections. One is shown in figure 5-8. You can construct this one by drawing OC vertical and using a protractor to draw OA and OB at 15° 00' to the horizontal. For this axis you foreshorten OA and OB in the ratio of 3/4 to 1 OC.

Another practical dimetric axis is shown in figure 5-9. You can construct this one by drawing OC vertical and then drawing OA and OB from 0 to 36° 50' to the horizontal. For this axis the foreshortening ratio is 3/4 OC to 1 OA and OB.

In figures 5-8 and 5-9 it is the side pairs of surfaces that make the same angle with the plane of projection, while the top and bottom pair makes a different angle. In figure 5-10 the top and bottom pair and one pair of side surfaces make the same angle, while the other pair of side surfaces makes a different angle. A practical dimetric axis for a cube in this position is shown in the figure. You can construct this one by

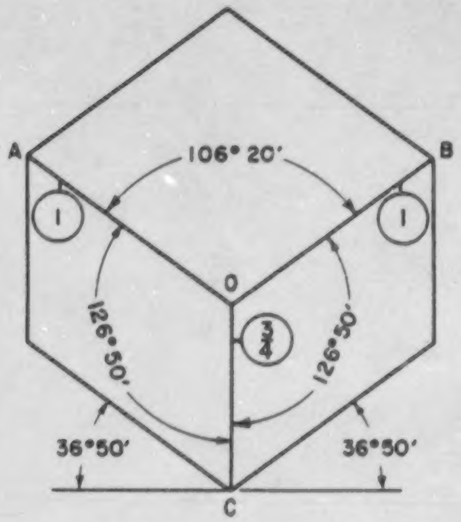

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Figure 5-9.—Dimetric projection of a cube, showing another practical dimetric axis.

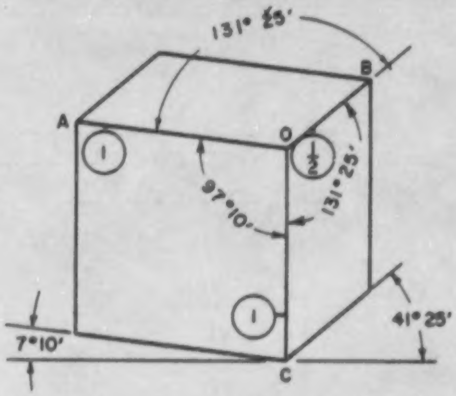

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Figure 5-10.—Practical dimetric axis for cube placed in different alignment.

drawing OC vertical; then drawing OA from 0 at 7° 10′ to the horizontal and OB from 0 at 41° 25′ to the horizontal. For this axis the foreshortening ratio is 1/2 for OB to 1 for OA and OC.

Trimetric Projection

In a trimetric projection the cube is inclined so that all three pairs of surfaces make different angles with the plane of projection. Figure 5-11 shows a trimetric projection of a cube. Because the foreshortening is different for each of the three pairs of surfaces, three different scales are required to scale down for foreshortening; hence the term "trimetric," meaning: "three-measure."

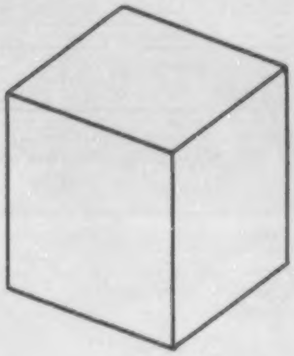

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Figure 5-11.—Trimetric projection of a cube.

MULTIVIEW ORTHOGRAPHIC PROJECTION

In a full-scale isometric drawing or cavalier projection, isometric or regular lines appear in their true dimensions. However, a cavalier projection shows many of the angles between regular lines incorrectly, and an isometric drawing shows all angles between isometric lines incorrectly. Furthermore, lines which are not isometric or regular lines are all projected incorrectly. For this and other reasons, most technical drawings are made by "multiplane" or "multiview" orthographic projection, rather than by cavalier projection or isometric drawing. In multiview orthographic projection an object, as it appears on all sides and in top and bottom views, is shown by the use of more than a single plane of projection. A surface parallel to the plane of projection appears in its true dimensions, and any lines or angles on the surface likewise appear true.

In short: of all the systems of projection commonly used for technical drawings, multiview orthographic projection is the one which is capable of projecting an object with the greatest completeness and accuracy.

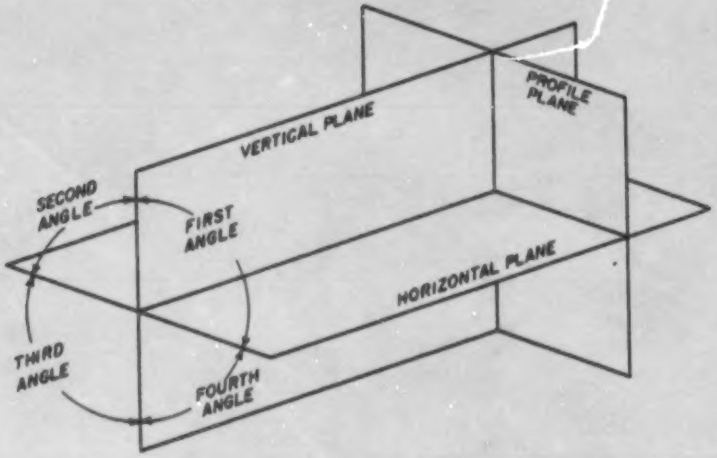

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Figure 5-12. — Multiview planes of projection.

MULTIVIEW PLANES OF PROJECTION

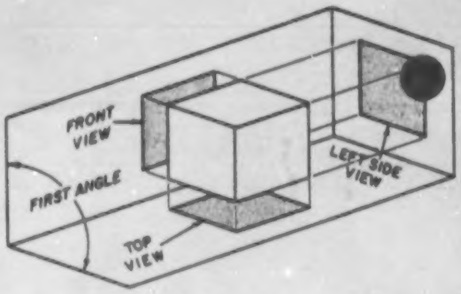
Figure 5-12 shows the three principal multiview planes of projection: the vertical plane, the horizontal plane, and the profile plane. Each plane is perpendicular to the planes it intersects. The right angles formed by the intersection of the vertical and horizontal planes are called the first, second, third, and fourth angles, located as indicated in the figure.

FIRST-ANGLE PROJECTION

The object to be projected could be considered to be placed in any one of the four angles mentioned. Second-angle and fourth-angle projections are not generally used. First-angle projection is used in most European countries.

Figure 5-13 shows the presumed position of a cube for first-angle projection. The front of the cube is toward the vertical plane of projection, the left side toward the profile plane. You get a front view on the vertical plane, a left-side view on the profile plane, and a top view on the horizontal plane.

To get all these views into the same plane, it is assumed that the horizontal plane is rotated clockwise and the profile plane counterclockwise. The projection then appears as shown in figure 5-14. This arrangement, which is considered satisfactory in Europe, is considered illogical in the U.S., because the top view is below the front view; because the left side view is toward the right side shown in the front view; and because the top view is toward the bottom as shown in the front view.

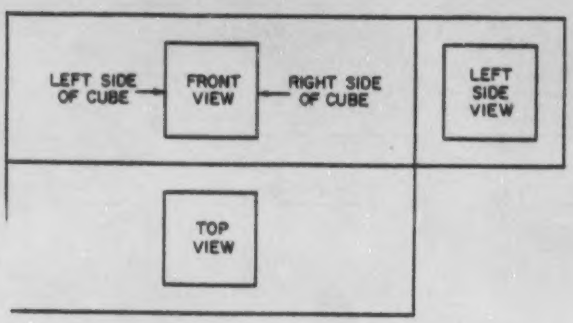


45.237
Figure 5-13. — First-angle projection.

THIRD-ANGLE PROJECTION

Third-angle projection, which is commonly used in the U.S., is shown in figure 5-15. As you can see, you get a front view on the vertical plane, a top view on the horizontal plane, and a right side view on the profile plane.

Figure 5-16 shows a wedge projected in a third-angle projection. The projected views were brought into a single plane. As you can se[illegible]he views are properly oriented in their na[illegible]al


LEFT SIDE OF CUBE
FRONT VIEW
RIGHT SIDE OF CUBE
LEFT SIDE VIEW
TOP VIEW

45.238
Figure 5-14.—First-angle projection brought into a single plane.

positions: the top view appearing above the front view and the right side view appearing to the right of the front view, with the front view serving as the point of reference.

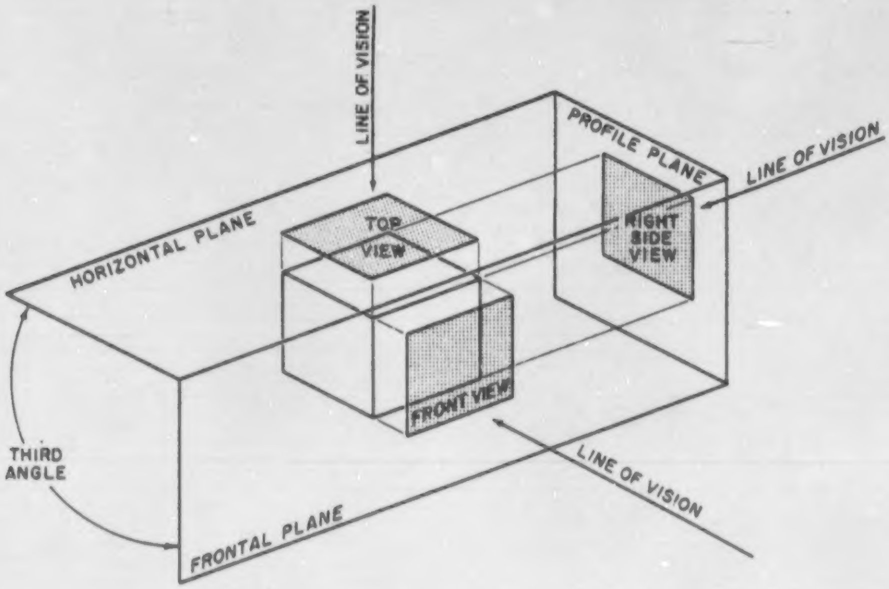
Figure 5-17 illustrates the method by which a third-angle projection is actually made. The horizontal line AB and the vertical line CD, intersecting at 0, are drawn first. AB represents the joint between the horizontal and the vertical planes. CD represents the joint between these and the profile plane.

Any one of the three views could be drawn first, and the other two projected from it. Assume that the front view is drawn first, on the basis of the given dimensions of the front face. You can then project the top view upward by vertical projectors, and the right side view to the right by horizontal projectors. The horizontal projectors from the top view, or the vertical projectors from the right side view, can be carried around from CD to AB, or from AB to CD, by a compass with needlepoint set at 0. Many draftsmen, however, prefer to carry the projectors around by one of the methods illustrated in figure 5-18.

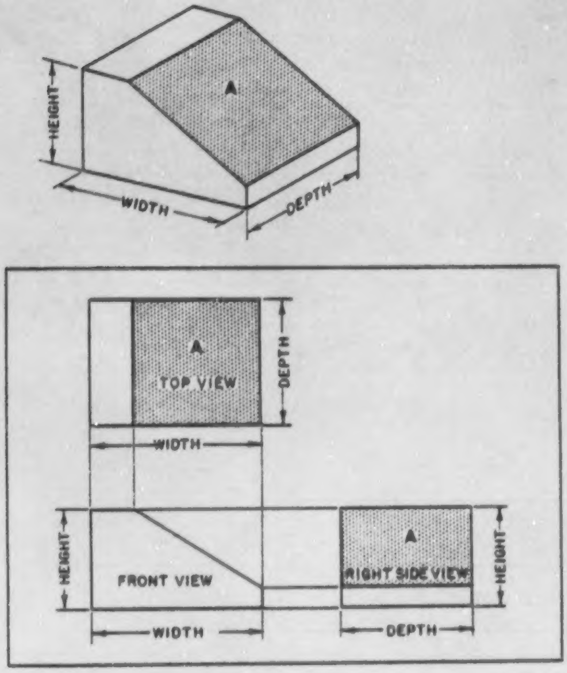
ARRANGEMENT OF VIEWS

The projection illustrated in figure 5-18 is a three-view orthographic projection, showing three faces of the block appearing as an oblique drawing in the top portion of the illustration. The block has six standard faces and a slanting face, A. Now let us assume that we replaced the cube shown in figure 5-15 with this block.

In theory, for a third-angle projection, there would still be only three planes of projection,


LINE OF VISION
PROFILE PLANE
LINE OF VISION
HORIZONTAL PLANE
TOP VIEW
RIGHT SIDE VIEW
FRONT VIEW
THIRD ANGLE
LINE OF VISION
FRONTAL PLANE

45.239
Figure 5-15.—Third-angle projection of a cube.

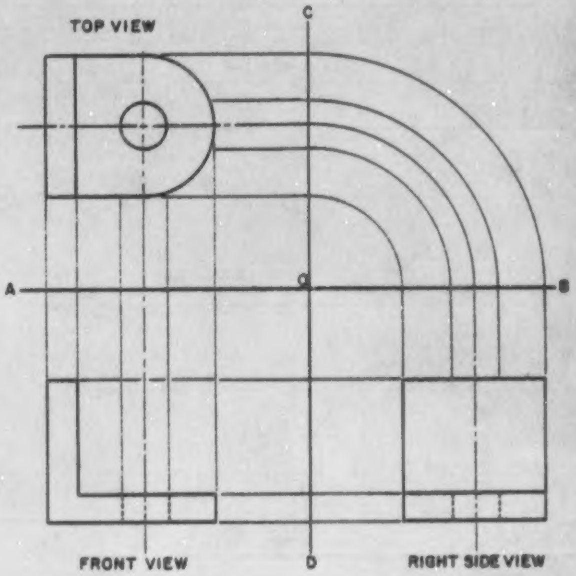


45.240(45B)
Figure 5-16.—Third-angle projection of a wedge shown in a single plane.

but for a back view (for example), the vertical plane would be presumed to be moved to a position between the observer and the back face of the block. Actually, this is the equivalent of assuming that there are six planes of projection, one between the observer and the object for each face of the block. For the moment, let us forget about the orthographic projection of the slanting face; this will be explained later in this chapter.

If only the front, top, and right side views are shown, the standard arrangement of views is as shown in parts A and B of figure 5-18, which is also the same as the arrangement of views shown in figures 5-16 and 5-17. If the left side, the bottom, and the back views of the block are shown as well, the standard arrangement of views will be as shown in figure 5-19.

In architectural drawings a top view is called a "plan" and a front, back, or side view an "elevation." A top view of a house, for example, is a plan; a top view of the land around a structure is a "plot" or "site" plan. A "floor" plan shows the top view of a house as it would look if the part of the house above the particular floor were cut away.



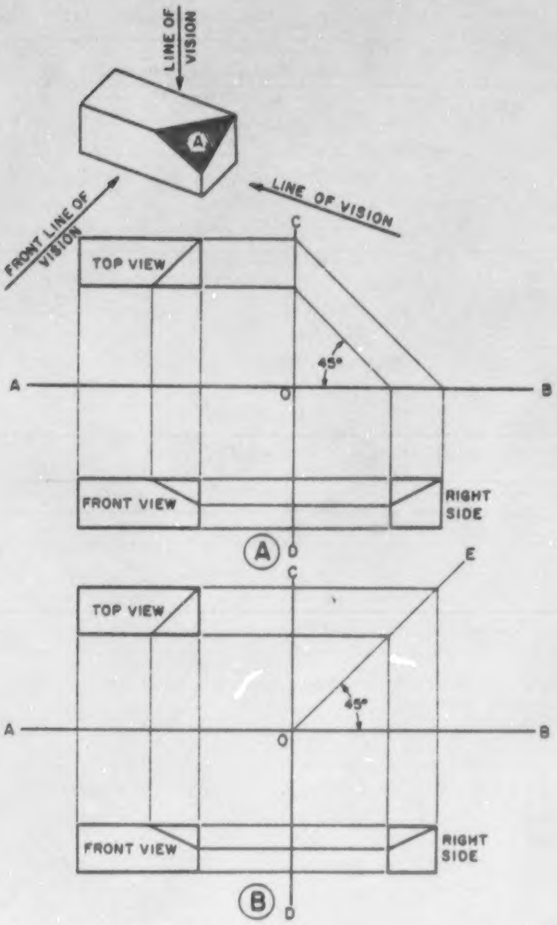
45.241(45B)
Figure 5-17.—Method of making a third-angle projection.

A front view of a house is a "front elevation," a back view is a "rear elevation," and a right side view is a "right side elevation." The terms, "plan" and "elevation," apply principally to architectural drawings, but they may also be applied to drawings of other than architectural objects.

VIEW ANALYSIS

You must be able to analyze a multiview projection—meaning, to determine what each line in a particular view represents with regard to the original object. In this connection, it is helpful to remember that in a third-angle projection the plane of projection is always presumed to be between the observer and the object for any view of the object. This means that, in a third-angle projection, each view of a surface shows the surface as it would appear to an observer looking directly at it.

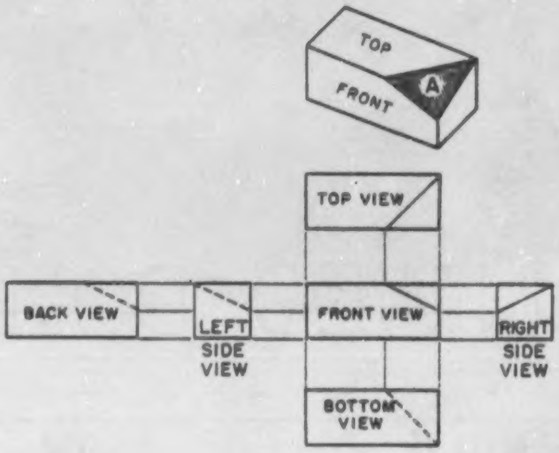
Figure 5-20 shows a six-view multiview third-angle projection of the block which is shown in cabinet projection in the upper left corner of the figure. You can easily analyze the


LINE OF VISION
A
FRONT LINE OF VISION
LINE OF VISION
C
TOP VIEW
45°
A
O
B
FRONT VIEW
RIGHT SIDE
A
D
C
E
TOP VIEW
45°
A
O
B
FRONT VIEW
RIGHT SIDE
B
D

45.242(45B)
Figure 5-18.—Alternate methods of extending top view projectors.

front view; you know that the top is up, the bottom is down, the left side is to YOUR left (NOT to the object's left), and the right side to your right.

It's also easy to see that in the top and bottom views the right-hand vertical line represents the right side and the left-hand vertical line the left side. But you may have to think a minute to realize that the upper horizontal line in the top view represents the BACK face of the block, while the lower horizontal line in the top view represents the FRONT face of the block. Note, also, that there is a line which appears as a


TOP
FRONT
A
TOP VIEW
BACK VIEW
LEFT SIDE VIEW
FRONT VIEW
RIGHT SIDE VIEW
BOTTOM VIEW

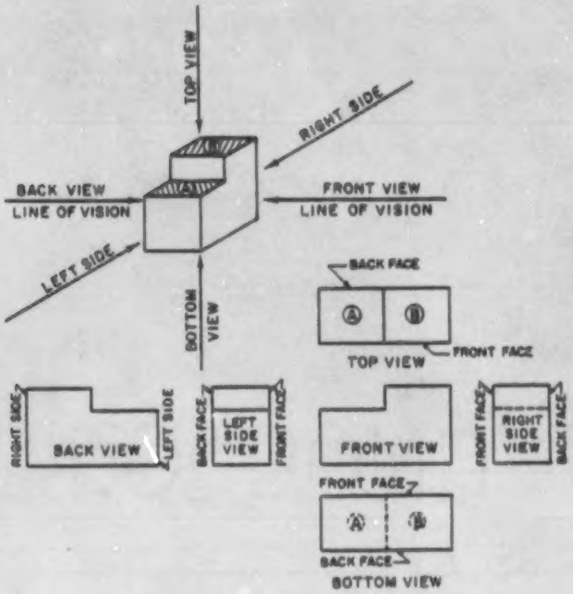
45.243(45B)
Figure 5-19.—American standard arrangement of views (six views); multiview third-angle projections.

visible line in the top view but as a hidden line in the bottom view.

In the right side and left side views you can readily see that the upper horizontal line represents the top of the block and the lower horizontal line the bottom. But you may have to think a minute to realize that the left-hand vertical line in the right side view represents the FRONT face of the block, while the left-hand vertical line in the left side view represents the BACK face. And again, there is a dotted line which appears as an invisible line or hidden line in the right side view, but as a visible line in the left side view.

In the back view the block is shown reversed, so that the cutaway part which appears to the left in the front view appears to the right in the back view. Similarly, the right-hand vertical line in the front view represents the right side of the block, but the corresponding line in the back view represents the left side.

In third-angle projection view analysis it is helpful to remember that in a top, bottom, or side view the line which represents the front face is the line which is toward the front view. Similarly, in a back view the line which repre-


TOP VIEW
RIGHT SIDE
BACK VIEW
LINE OF VISION
FRONT VIEW
LINE OF VISION
LEFT SIDE
BOTTOM VIEW
BACK FACE
A
B
TOP VIEW
FRONT FACE
RIGHT SIDE
BACK VIEW
LEFT SIDE
BACK FACE
LEFT SIDE VIEW
FRONT FACE
FRONT VIEW
FRONT FACE
RIGHT SIDE VIEW
BACK FACE
FRONT FACE
A
B
BACK FACE
BOTTOM VIEW

45.244(45B)
Figure 5-20.—Multiview analysis.

sents the left side face is toward the right side view.

CHOICE OF VIEWS

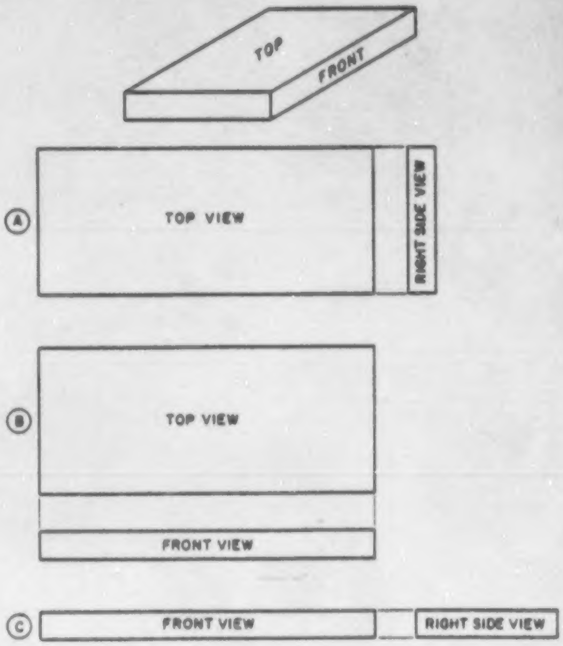
A multiview projection should contain only the minimum number of views required for complete description of the object. If you refer back to figure 5-20 you will see that the back view does not convey any information which is not available in the front view. The back view is therefore superfluous and should be omitted. The same applies to the bottom view, which conveys no information which is not available in the top view; and to the left side view, which conveys no information not available in the right side view.

You have the choice, then, of omitting either the back view or bottom view, and either the right side or left side view. There is a general rule that a top view has priority over a bottom view and a right side view over a left side view; however, if the left side view will give more information, it must be used instead of the right side view. A view with a visible line is preferable to a view in which the same line appears as a hidden line. Generally, in practice, the bottom and left side views are seldom used. Only a three-view projection, showing top, front, and right side views, is required.

It is often the case that only a two-view projection is required. In figure 5-21 a top view shows everything you need to know except the thickness; a right side view shows everything you need to know except the length; and a front view shows everything you need to know except the width. All you need to do, then, is select one view and couple it with another which shows the information missing in the first one.

There are three possible two-view combinations which convey complete information, as shown in A, B, and C (fig. 5-21). In the selection of one of these, everything else being equal, the balanced appearance of the drawing would be the deciding factor. Either A or B appears better balanced than C. As between A and B, A would look better on a long oblong sheet of paper and B better on a shorter oblong sheet.

The object shown in figure 5-21 has a definitely designated top and front, which means that the right and left sides are also definitely designated. This is the case with many objects—with a house, for example, you have no choice as to


TOP
FRONT
A
TOP VIEW
RIGHT SIDE VIEW
B
TOP VIEW
FRONT VIEW
C
FRONT VIEW
RIGHT SIDE VIEW

45[illegible]5
Figure 5-21.—Two-view multiview project[illegible]s.

which surface shall be called the top. Many objects, however, have no definite top, bottom, front, or back—many types of machine parts, for example. With an object of this kind you can select a surface and call it the front, top, right side, and so on, according to convenience.

However, there is a general rule that an object should be shown in the position it customarily occupies. Suppose that the object shown in figure 5-21 is a floor board. Then the top would be as indicated in the figure. If it were a wall board, however, one of the long narrow edges would be the top and one of the broad faces the front.

SPACING VIEWS

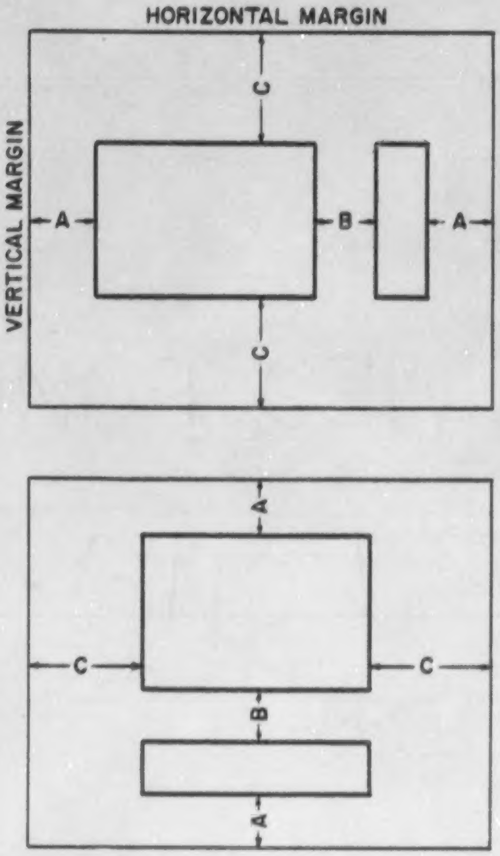
Views should be spaced on the paper so as to give a balanced appearance. Figure 5-22 shows two-view drawings properly spaced on size A (8-1/2 in. x 11 in.), size C (17 in. x 22 in.), or size E (34 in. x 44 in.) drawing paper. Marginal distances should be equal as indicated. Distance B should be equal to, or slightly less than, distance A.

A convenient way to determine the length of distance A in the upper drawing shown in figure 5-22 is as follows. Set a compass to the length plus the thickness of the object (to the scale of the drawing, of course), and lay off this distance from the end of one of the horizontal margins of the drawing. Distance A should be made equal to one-third of the length of the remaining segment of the horizontal margin.

To determine the length of distance C in the same drawing, set a compass to the width of the object and lay off this distance from the end of one of the vertical margins. Distance C should be made equal to one-half the length of the remaining segment of margin.

Proper spacing of a three-view drawing is shown in figure 5-23. As you can see, the principle is the same as that applied in spacing a two-view drawing. Distances are again equal as indicated, with distance B equal to, or slightly less than, distance A, and distance D equal to, or slightly less than, distance C.

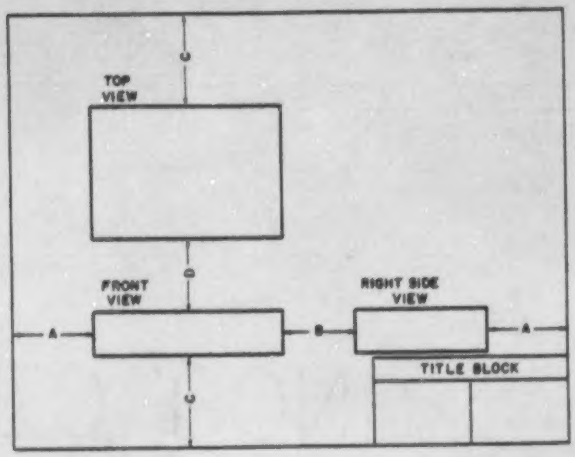
While the spacing of views in figure 5-23 is technically correct, the drawing has an unbalanced appearance, because of the large area of empty space in the upper right and because the right side view crowds the title block. However, if the area of empty space will be occupied by a sizeable bill of materials, the present spacing will be satisfactory. If not, it should be improved if possible.



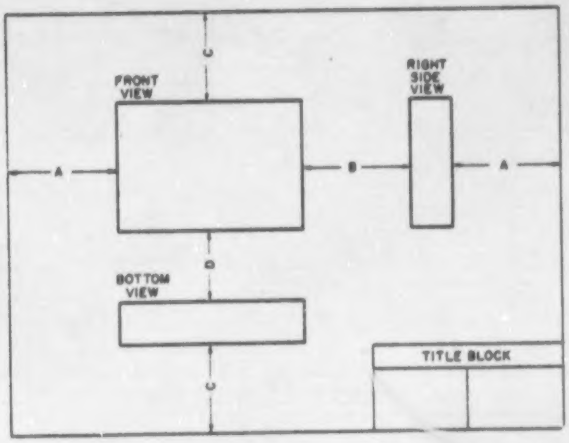
45.246
Figure 5-22.—Proper spacing of views on a two-view projection.

If the object is one which permits arbitrary designation of surfaces as front, top, right side, and so on, the spacing can be improved by changing the surface designations and projecting the object as shown in figure 5-24. What appears as the top in figure 5-23 now appears as the front, and the front of figure 5-23 appears as the bottom in figure 5-24. The right side view now appears in the upper rather than in the lower right corner, and vertically rather than horizontally.

Spacing views in a drawing of a circular object is like spacing letters, in that you try to equalize the spaces around and between the views. Figure 5-25 shows properly spaced two-view drawings of a perforated disk. For the arrangement in horizontal line you locate the horizontal center-

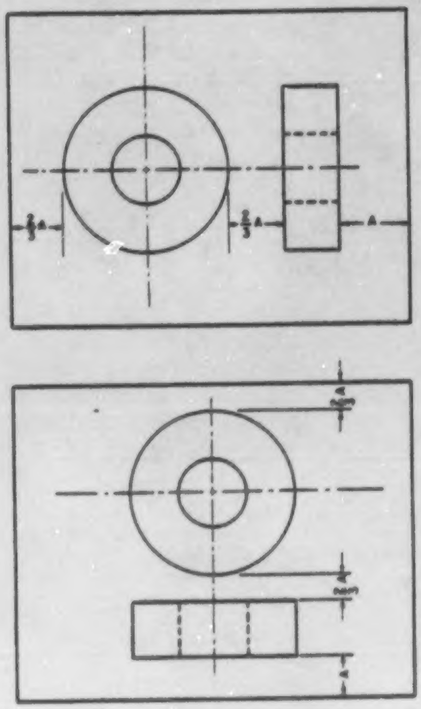


45.247
Figure 5-23.—Proper spacing of views on a three-view projection.



45.248
Figure 5-24.—Improved spacing for three-view projection of object shown in figure 5-23.

line midway between the horizontal margins. For the arrangement in vertical line you have to consider the diameter and the thickness of proportional measurements from the vertical margins or along one of the horizontal margins. The other spacing is as indicated. Because of the circular character of the object, the spaces



45.249
Figure 5-25.—Spacing of views of a circular object.

marked 2/3 A appear about equal to the spaces marked A.

To determine actual distances A and 2/3 A, set a compass to the diameter plus the thickness of the disk, and lay off this distance from the end of a horizontal margin for the upper drawing, or from the end of a vertical margin for the lower drawing. Then divide the remainder of the margin into three intervals, two of them equal and the third, 1-1/2 times as long as each of the others. The third interval equals A; each of the others equals 2/3 A.

HIDDEN LINE TECHNIQUES

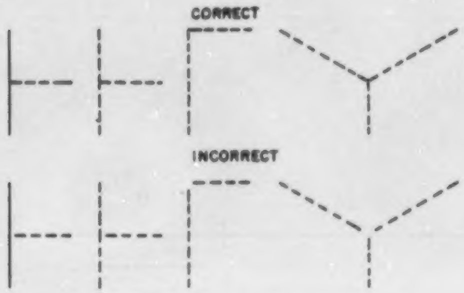
To prevent confusion in the interpretation of hidden lines, certain standard techniques must be applied in drawing these lines. A hidden line which is supposed to join a visible or another hidden line must actually contact the line as shown in the upper views of figure 5-26. Incorrect procedures are shown in the lower views.

Figure 5-27 shows an intersection between a hidden line and a visible line. Obviously, on the object itself the hidden line must be below the visible line. You indicate this fact by drawing the hidden line as shown in the upper view of figure 5-27. If you drew it as indicated in the lower view, the hidden line would appear to be above, rather than below, the visible line.

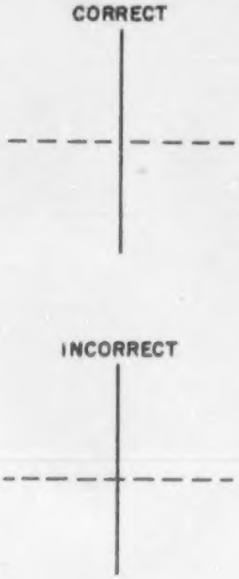
Figure 5-28 shows an intersection between two hidden lines, one of which is beneath the other on the object itself. You indicate this fact by drawing the lines as indicated in the upper view of figure 5-28. If you drew them as indicated in the lower view, the lower line would appear to be uppermost.

NUMBERING CORNER POINTS

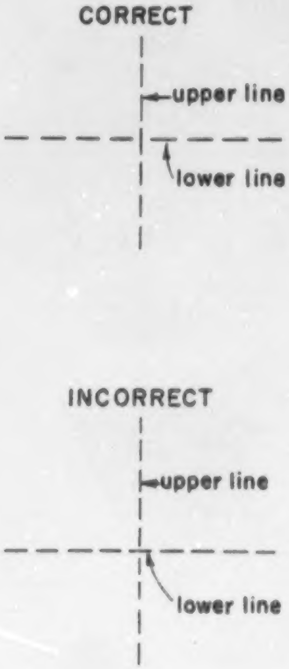
A point which constitutes a corner on an object is sometimes numbered for purposes of identification in various views of the object. In a particular view of an object, a corner point may be visible or it may be hidden, as shown in figure 5-29. In the upper left corner of the figure there is an oblique projection of a block, with a corner numbered 2. You can see that this corner is visible in top, back, and right side



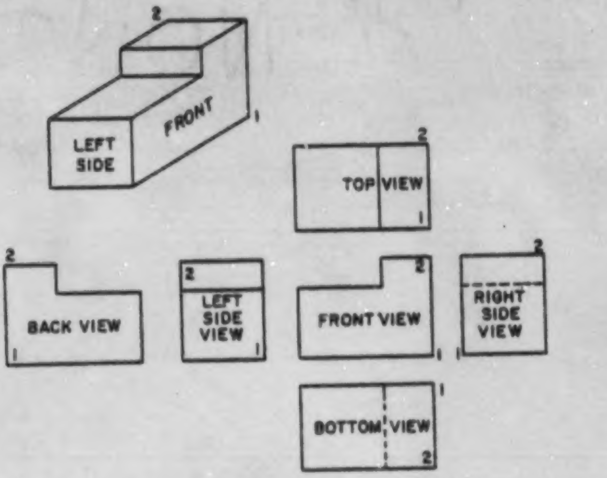
45.250
Figure 5-26.—Correct and incorrect procedures for drawing adjoining hidden lines.



45.251
Figure 5-27.—Correct and incorrect procedures for drawing hidden line which intersects visible line.



45.252
Figure 5-28.—Correct and incorrect procedures for drawing intersecting hidden lines which are on different levels.



45.253
Figure 5-29.—Procedure for numbering hidden and visible corner points.

views, but hidden in bottom, front, and left side views.

The rule for numbering is that for a hidden corner point the number is placed within the outline, and for a visible corner point outside the outline. You can see how the rule has been followed in figure 5-29.

NORMAL AND NON-NORMAL LINES

In a multiview orthographic projection a NORMAL line is one which is parallel to two of the planes of projection and perpendicular to the third. A line which is parallel to a plane of projection will appear on that plane in its true length (to the scale of the drawing). A line which is perpendicular to a plane of projection will appear on that plane as a point.

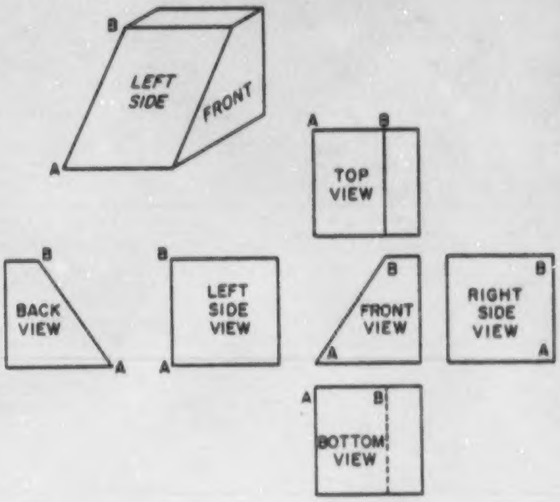
A line which is perpendicular to one plane of projection must of necessity be parallel to the other two. But a line which is parallel to one plane of projection may be oblique (neither parallel nor perpendicular) to one or both of the others. A line which is oblique to one or more of the planes of projection is called a NON-NORMAL LINE.

If a non-normal line is parallel to a plane of projection, it will appear on that plane in its true length. However, it will appear foreshortened in a view on a plane to which it is oblique. A non-normal line may, of course, be oblique to all three planes of projection, in which case it will appear foreshortened in all regular views of the object. A REGULAR VIEW is a view on one of the three regular planes of projection (horizontal, vertical, or profile). Views on planes other than the regular planes are called AUXILIARY VIEWS (see later).

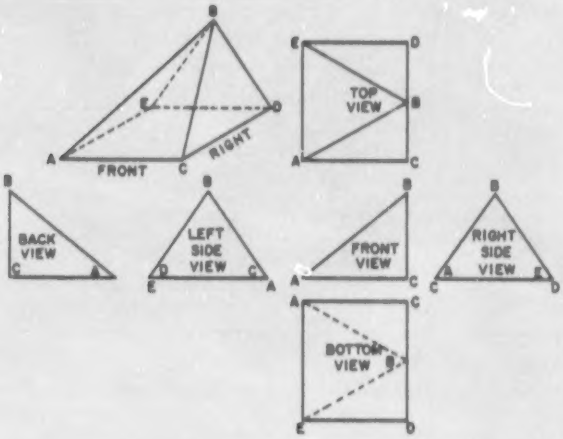
In the upper left corner of figure 5-30 there is an oblique projection of a block. This block is presumed to be placed for multiview projection with front parallel to the vertical plane, bottom parallel to the horizontal plane, and right side parallel to the profile plane. The line AB, then, is parallel to the vertical plane, but oblique to both the horizontal and the profile planes.

In the multiview projections you can see that it is only in the views on the vertical plane (the front and back views) that the line AB appears in its true length. In the views on the horizontal plane (top and bottom views) and in the views on the profile plane (right and left side views) the line appears foreshortened. Note, however, that you don't need to calculate the amount of the foreshortening, since it works itself out as you project the various views.

In the upper left of figure 5-31 there [illegible] oblique projection of a triangular block, the base



45.254
Figure 5-30.—Foreshortening of a line [illegible] a multiview projection.



45.255
Figure 5-31.—A line oblique to all planes of projection is foreshortened in all views.

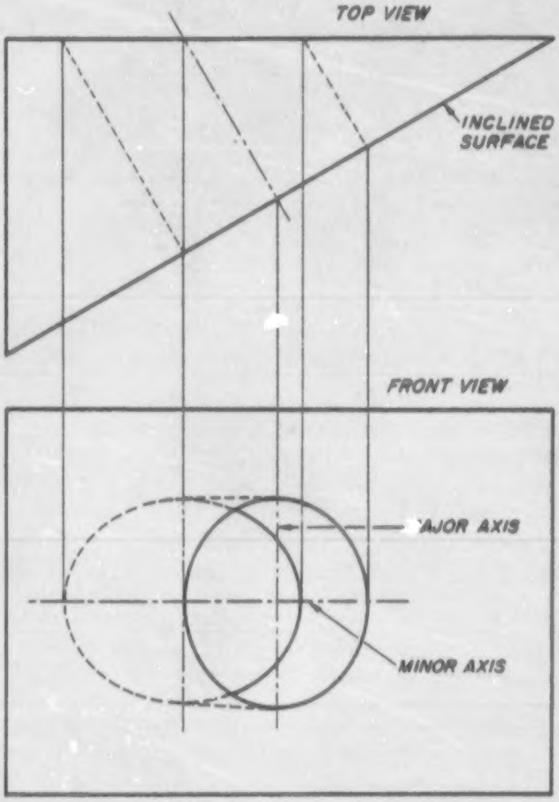
of which is rectangular. This block is presumed to be placed for multiview projection with right side parallel to the profile plane. The line AB, then, is oblique to all three regular planes of projection.

The true length of AB is the hypotenuse of the slanting right triangle ABC, with its altitude equal to BC and its base equal to AC. You can see that AB is foreshortened in all regular multiview views.

CIRCLES IN MULTIVIEW ORTHOGRAPHIC PROJECTION

A circle on a surface which is parallel to the plane of projection will project as a circle. One on a surface which is oblique to the plane of projection, however, will project as an ellipse, as shown in figure 5-32. The upper view in this figure is a top view of a wedge, the wedge having a hole bored through it perpendicular to the inclined face. The outline of this hole on the front face of the wedge projects as an ellipse in the front view. You get the minor axis of the ellipse by projecting downward as shown. The length of the major axis is equal to the diameter of the hole.

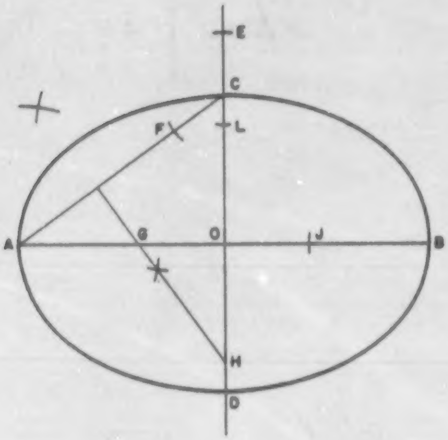
There is another ellipse in the front view: the partly hidden and partly visible outline of the hole as it emerges through the back of the wedge. The back of the wedge is parallel to the front view plane of projection; therefore, this ellipse is the true outline of the hole on the back of the wedge. The outline is elliptical because the hole, though it is circular, is bored oblique to the back face of the wedge.



45.256
Figure 5-32.—A circle on a surface oblique to the plane of projection projects as an ellipse.

To draw these ellipses you could use any of the methods of drawing an accurate ellipse explained in the previous chapter on geometric construction. However, in a case of this kind an approximate ellipse, which can be quickly and easily drawn with a compass, is usually satisfactory.

A method of drawing an approximate ellipse on given major and minor axes is shown in figure 5-33. Set a compass to the length of AO, and with 0 as a center strike an arc intersecting OC (extended) at E. Draw AC, set the compass to the length of CE, and with C as a center strike an



23.245
Figure 5-33.—Method of drawing an approximate ellipse with a compass.

arc intersecting AC at F. Bisect line AF and draw a perpendicular bisector from AF, intersecting AO at G and OD at H. Lay off OJ equal to GO and OL equal to OH. With H as a center, draw a circular arc through C, and with L as a center draw a circular arc through D. With G as a center, draw a circular arc through A, and with J as a center draw a circular arc through B. These arcs will connect to form an approximate ellipse.

AUXILIARY VIEWS

In theory, there are only three "regular" planes of projection: the vertical, the horizontal, and the profile. Actually, it is presumed that each of these is, as it were, double; there is, for example, one vertical plane for a front view and another for a back view.

We assume, then, a total of six regular planes of projection. A projection on any one of the six is a regular view. A projection NOT on one of the regular six is an AUXILIARY view.

The basic rule of dimensioning requires that a line be dimensioned only in the view where its true length is projected and that a plane with its details be dimensioned only in the view where its true shape is represented. In order to satisfy this rule, we have to create an imaginary plane that is parallel with the line or surface we want to project in its true shape. A plane of this kind—which is not one of the regular planes—is called an AUXILIARY PLANE.

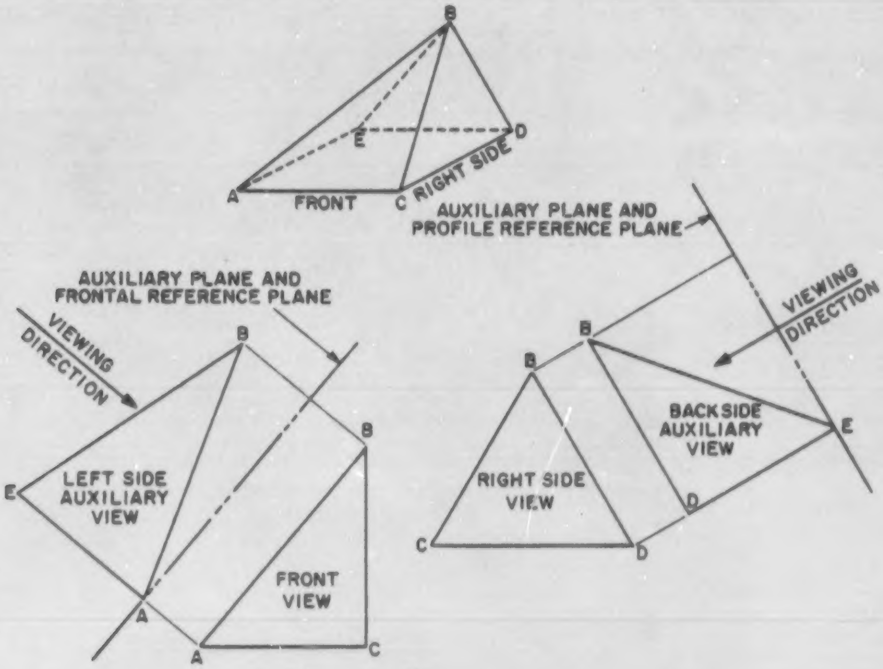
Figure 5-34 illustrates the method of projecting an auxiliary view. In the upper left of the figure there is a block with a triangular inclined face. It is desired to project a view of this inclined face which will show the face in its true dimensions. The inclined face is oblique to all the regular planes of projection; therefore, it must be projected onto an auxiliary plane.

First you select a regular view in which the inclined face appears as a straight line. It so appears in the regular front view as represented by AB. Draw the "auxiliary plane and reference plane" line parallel to the straight line representation of the inclined face (that is, parallel to the line AB in the front view). The line marked "auxiliary plane and frontal reference plane" represents an edge-view of the auxiliary plane of projection. In theory the auxiliary projection is made on this plane and then rotated into the plane of the paper. In this case the line marked "auxiliary plane and frontal reference plane" also represents an edge view of the reference plane from which the width of the auxiliary view will be laid off.

As you can see in figure 5-34, the left side auxiliary view was projected from the front view using a frontal reference plane, and the back [illegible] auxiliary view was taken from the right side [illegible] using a profile reference plane. The following facts must be considered in the drawing of auxiliary views:

1. FRONT OR REAR AUXILIARY VIEWS are always projected from a side view. The viewing direction is profile, and the reference is the profile plane. It will show the true width of the object. For a simpler interpretation of auxiliary projection, it is good practice to orient their respective edges or sides in their natural positions, as for example, the positions of sides AB and BD in figure 5-34.
2. RIGHT OR LEFT AUXILIARY VIEWS are always projected from the front view. The viewing direction is frontal and the reference plane is frontal. The projection will show the true depth of the object. The front edge of the object is always drawn nearest to the front view.
3. AN ELEVATION AUXILIARY VIEW is always projected from the top view. The viewing direction will be horizontal and the plane of reference is horizontal. The projection will show the true height of the object. The top edge of the object will always be nearest the top view.

In figure 5-34, the auxiliary plane line [illegible] the reference plane line coincide. This is [illegible]


B
E
D
A
FRONT
C
RIGHT SIDE
AUXILIARY PLANE AND PROFILE REFERENCE PLANE
AUXILIARY PLANE AND FRONTAL REFERENCE PLANE
VIEWING DIRECTION
B
B
E
LEFT SIDE AUXILIARY VIEW
FRONT VIEW
A
A
C
VIEWING DIRECTION
B
B
BACK SIDE AUXILIARY VIEW
E
RIGHT SIDE VIEW
D
C
D

45.258(45B)
Figure 5-34.—Projecting auxiliary views.

necessarily the case, however. You might find ti more convenient to locate the reference plane line as it is placed in the upper or the lower projection of figure 5-35. Both projections illustrated in figure 5-35 are the left side auxiliary projections taken from the front view shown in figure 5-34. In both of these projections the auxiliary plane is still presumed to be between the front view and the auxiliary view.

As mentioned earlier, the purpose of an auxiliary view in a drawing is to project nonnormal lines or surfaces (those oblique to the regular plane of projection) in their true dimensions. However, there are cases where an auxiliary view may be desired to simply show how an object looks from a given angle of observation; in such a case, dimension is of secondary importance.

In the upper left corner of figure 5-36, there is an oblique projection of an L-shaped block. Ordinarily, this is considered a regular L-shaped object that requires a regular plane of projection; however, if one desires to take an auxiliary view as it would appear from the angle of observation indicated by the arrow, the auxiliary plane of projection in this case is, of course, perpendicular to the arrow.

DOUBLE AUXILIARY VIEWS

To show the inclined face of the block illustrated in figure 5-34 in its true dimensions, only a single auxiliary view was necessary. The reason was the fact that there was a regular view (the front view) in which the back surface appeared as a straight line.

When this is not the case, a PRIMARY auxiliary, in which the surface in question appears as a straight line, must be projected first. Then a SECONDARY auxiliary, in which the surface appears in its true dimensions, must be projected from the primary auxiliary.

In the upper left of figure 5-37 there is an oblique projection of a block. The surface marked A is oblique to all three regular planes of projection, which means that there is no regular view in which the surface will appear as a straight line.

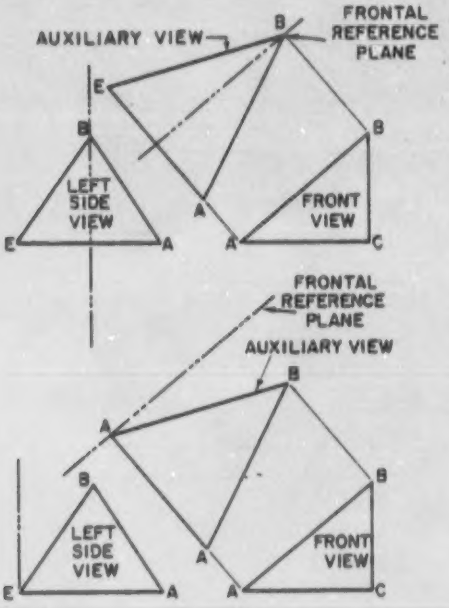


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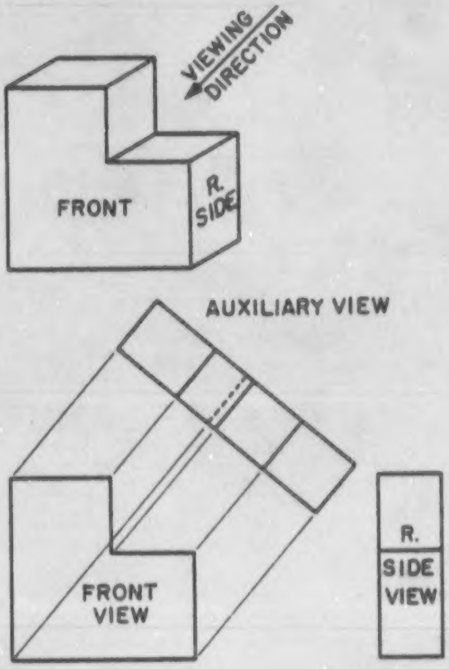
Figure 5-35.—Alternate locations of reference plane line.



45[illegible]

Figure 5-36.—Auxiliary view showing object as seen from a particular angle of observation.

To construct the primary auxiliary you must project the block onto a plane which is perpendicular to surface A, because it is only on such a plane that surface A will appear as a straight line.

The line XX shown on the front view (fig. 5-37) is perpendicular to the line 1-3; it is therefore an edge view of a plane perpendicular to surface A. If you project the front view onto an auxiliary plane parallel to XX, you get a primary auxiliary view in which surface A appears as a straight line (edge 3-2 is seen in this case).

If you project the primary auxiliary view (fig. 5-37) onto a plane parallel to surface A in that view, you get a secondary auxiliary view in which surface A appears in its true dimensions. You can see that the reference plane line X'X' in the secondary auxiliary view is parallel to surface A as it appears in the primary view. You project the secondary view from the primary view by projectors drawn perpendicular to X'X'. You locate points on these projectors above and below X'X' by measuring the corresponding distances above and below XX in the front view from which the primary view was projected.

TRUE LENGTH OF A LINE FROM PARTIAL AUXILIARY VIEW

A non-normal line appears foreshortened in all regular multiview views. The true length of such a line can be determined by means of a partial auxiliary view, one which shows the line as it would appear on a plane of projection to which it is parallel.

In the upper left corner of figure 5-38 there is an oblique projection of a triangular block. The line AB is shown in its true length in the small right triangle to the right. In the regular multiview projections shown below (top view and front view), AB appears foreshortened.

In the front view, AB appears as a straight line. You can determine the true length of AB by projecting it onto the parallel plane X'X', as shown. X'X' is also a reference plane line, corresponding to XX in the top view. Point B in the partial auxiliary view is located on the projector from B in the front view, at a distance from X'X' equal to the distance from B to XX in t[illegible]op

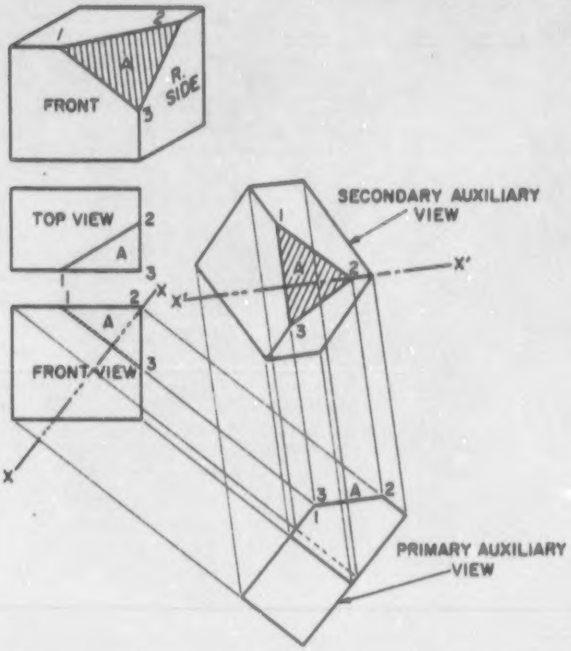


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Figure 5-37.—Double, or primary and secondary auxiliary views.

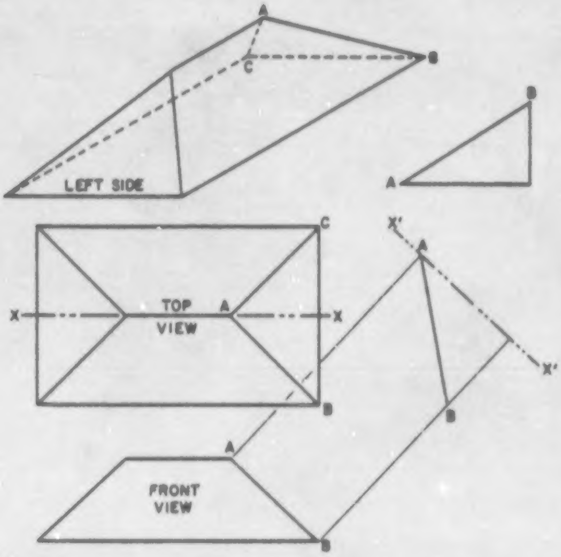

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Figure 5-38.—Projecting a partial auxiliary view to get the true length of a line.

view. AB appears in its true length in the partial auxiliary view.

AUXILIARY SECTION

An auxiliary view may be a sectional rather than a surface view. In the upper left of figure 5-39 there is a cabinet projection of a block. It is desired to show the right side of the block as it would appear if the block were cut away on the plane indicated by the dotted line, the angle of observation to be perpendicular to this plane. The desired view of the right side is shown in the auxiliary section, which is projected from a front view as shown. Because the auxiliary plane of projection is parallel to the cut away surfaces, these surfaces appear in true dimensions in the auxiliary section.

REVOLUTIONS

A regular multiview of an orthographic drawing is one which is projected on one of the regular planes of projection. An auxiliary view is one which is projected on a plane other than one of the regular planes.

A rectangular object is in "normal position" for regular multiview orthographic projection when each of its faces is parallel to one regular plane of projection and perpendicular to the other two. This is the case with the object shown in figure 5-40, view A.

In a REVOLUTION the object is projected on one or more of the regular planes of projection. However, instead of being placed in normal position, the object is "revolved" on an axis perpendicular to one of the regular planes.

Figure 5-40, view B is a three-view multiview projection showing the block in view A of figure 5-40 as it would appear if it were revolved 30° on an axis perpendicular to the profile plane of projection. Figure 5-41, view A shows the block as it would appear if it were revolved 30° on an axis perpendicular to the horizontal plane. Figure 5-41, view B shows the block as it would appear if it were revolved 30° on an axis perpendicular to the vertical plane.

REVOLVED SECTIONS

A common use of the revolution is the revolved section illustrated in figure 5-42. At the

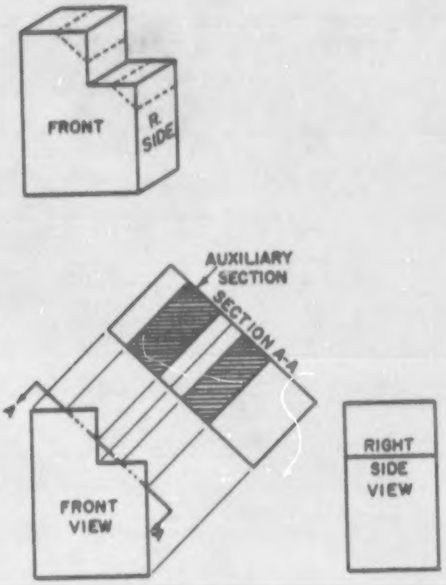

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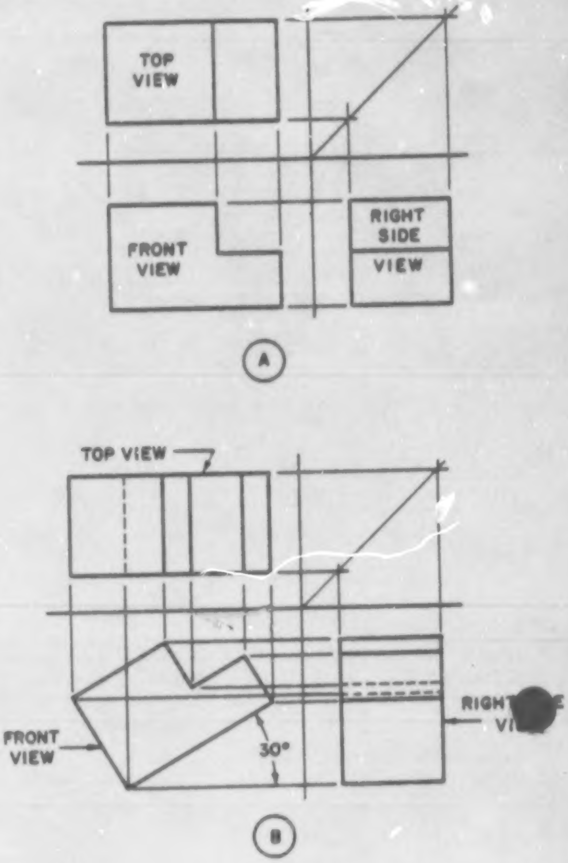
Figure 5-39.—Auxiliary section.



45.264
Figure 5-40.—(A) Multiview view of block in normal position. (B) Multiview view of block revolved 30° on axis perpendicular to vertical plane.

top of this figure there is a cabinet projection of a triangular block. You can show all required information about this block in two-view projection by including a revolved section in the front view as shown. You first assume that the block is cut by a plane perpendicular to the longitudinal axis. You then revolve the resulting section 90° on an axis perpendicular to the horizontal plane of projection.

SECTIONING TECHNIQUES

A section view is called for when the internal structure of an object can be better shown in such a view than it can by hidden lines. In the upper part of figure 5-43 there is a cabinet projection of a pulley. The same object is shown below in a two-view multiview projection. The internal structure of the pulley is shown by the hidden lines in the top view.

In figure 5-44 the internal structure of the pulley is much more clearly shown by a section view. Note that hidden lines behind the plane of projection of the section are omitted in the section view. These lines are omitted by general custom, the custom being based on the fact that the elimination of hidden lines is the fundamental reason for making a section view. However, any lines which would be VISIBLE behind the section plane of projection must be included in the section view.

Full and Half Sections

The section shown in figure 5-44 is called a full section, because the cutting plane passes entirely through the object and divides it into two equal parts. Also, the object shown in figure 5-44 is a symmetrical object—meaning, in general, that the shape of one half is identica th

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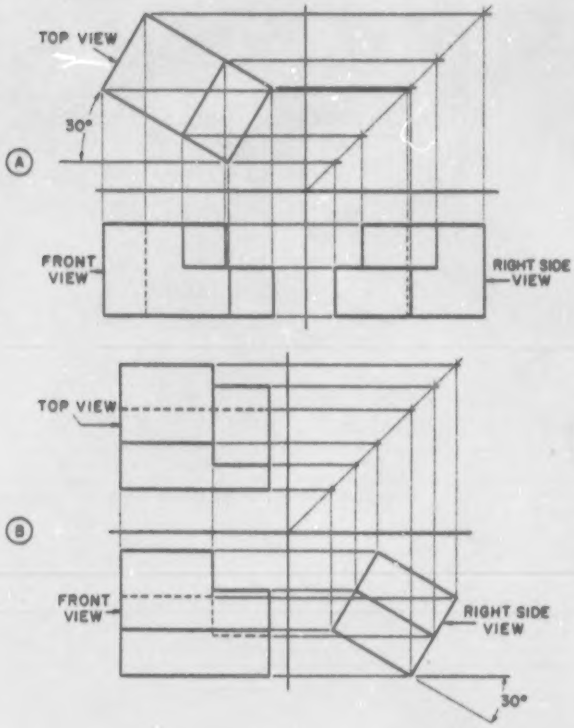

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Figure 5-41.—(A) Revolution on axis perpendicular to horizontal plane. (B) Revolution on axis perpendicular to vertical plane.

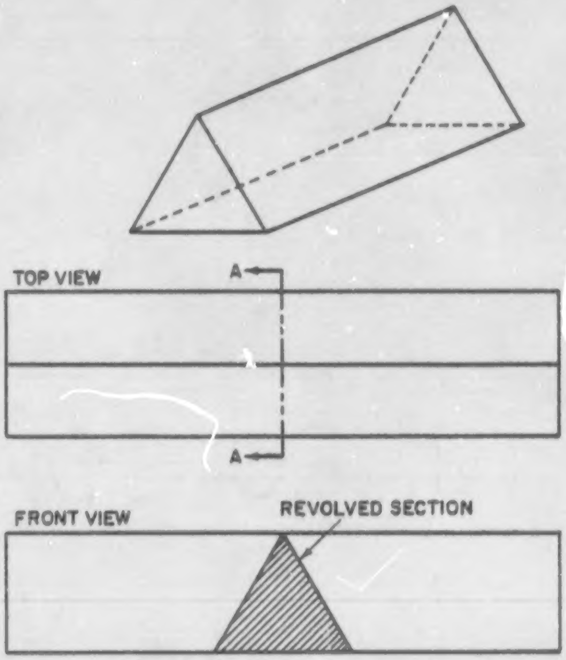

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Figure 5-42.—Revolved section A-A.

the shape of the other. This being the case, you could have used a half section like the one shown in figure 5-45. This half section constitutes one-half of the full section. Because the other half of the full section would be identical with the half shown, it need not be drawn.

Note that a centerline, rather than a visible line, is used to indicate the division between the sectioned and the unsectioned part of the section view. A visible line would imply a line which is actually nonexistent on the object. Another term used in place of centerline is "line of symmetry."

Partial or Broken Section

A section consisting of less than a half section is called a partial section (see fig. 5-46). Note that here you use a break line to indicate the division between the sectioned and unsectioned part. For this reason a partial section is often called a broken section.

Section Lining Techniques

The lines drawn on a sectional surface always serve the basic purpose of indicating the limits of the sectional or cut-away surface. They may also serve to indicate the material of which the sectioned surface consists, as explained in the previous chapter.

When the section lines are intended to indicate material, cast iron is indicated by a pattern of slanting, parallel lines called diagonal hatching. On drawings on which the section lines are not intended to indicate material, diagonal hatching is used for all sectioned surfaces.

Angle of Diagonal Hatching

On a regular multiview section on an object in normal position the diagonal hatching should be drawn at 45° to the horizontal, as shown in figure 5-47, view A. If two adjacent sectioned

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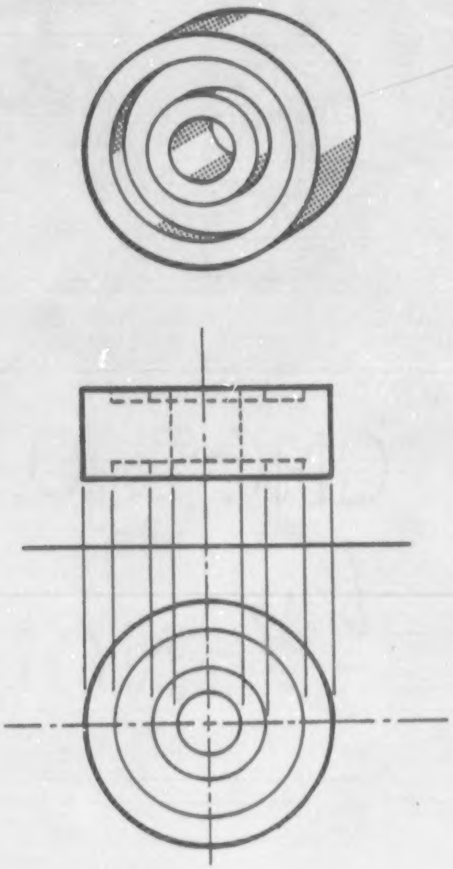

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Figure 5-43.—Internal structure shown by hidden lines.

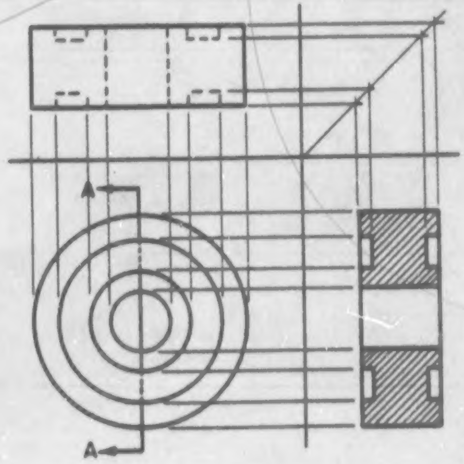

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Figure 5-44.—Internal structure more clearly shown by sectional view.

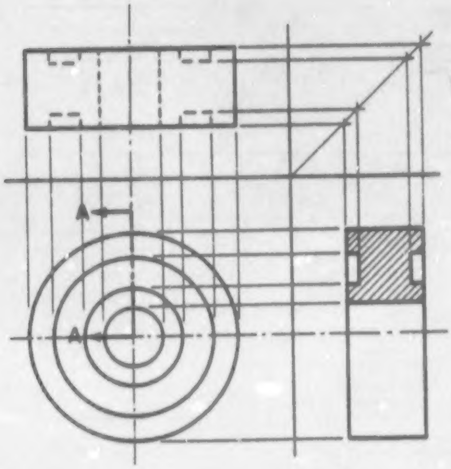

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Figure 5-45.—Half section.

surfaces are shown, the hatching should be inclined in opposite directions as shown in figure 5-47, view B. If still a third surface is included, it should be hatched at an angle of 30°, as shown in figure 5-47, view C. Note that the hatching lines on one surface are not permitted to meet those on an adjacent surface.

Diagonal hatching on an auxiliary section should be drawn at 45° to the horizontal, as the horizontal exists with respect to the section. Figure 5-48 illustrates this rule.

In a revolution or other view of an object in other than normal position the diagonal hatching on a section should be drawn at 45° to the horizontal or vertical axis of the object as it appears in the revolution. Figure 5-49 illustrates this rule.

ISOMETRIC DRAWING TECHNIQUES

Earlier in this chapter, we discussed the theory of isometric projection and isometric drawing. As you have learned, the principle of isometric projection is employed in isometric drawing, with one important difference: the foreshortening effects of lines of the object in isometric projection are disregarded in isometric drawing. The following paragraphs will discuss method of drawing an approximate ellipse will work only when the conjugate diameters are equal in length.

PERSPECTIVE DRAWING

Perspective drawings are one-view drawings constructed by perspective projection. While they do not show the object in its true shape and dimensions, they do show how the object would look naturally to an observer, and as a consequence, they are easier to comprehend at a glance than drawings made according to orthographic projection. For this reason, perspective projection is often used for exploded views of objects to show all the different parts and their relationship to each other. Oblique drawings could suffice for the same purpose; however, perspective drawings are more presentable in appearance. Perspective projection is generally used for architectural renderings of proposed structures (especially residential houses) to show how the structures will look when they are completed. This perspective will also depict how a proposed structure will blend-in with the existing environment.

These architectural renderings are generally referred to in the Seabees as "Presentation Drawings." The preparation of a presentation drawing requires special skills.

Perspective projection drawings requiring very accurate projection are usually done by working from orthographic views of the object. For purposes of illustration, however, this type of painstaking projection is not necessary. Many illustrators do not use the methods of perspective projection at all, making their perspective drawings by approximating the positions of various planes. But, unless you are a very keen observer and have had considerable practice in the art, you are likely to commit some rather ridiculous errors if you try to draw perspective illustrations by guesswork alone. A few simple rules and a few pains taken in constructing a scene or an object will help you make a better drawing. In the following sections we will discuss some of the techniques used in perspective projection; however, for an intensive study of the subject, you should consult one of the various textbooks on drafting that treats perspective drawing quite thoroughly.

ONE-POINT PERSPECTIVE

Figure 5-64 is a one-point perspective projection of a cube from a top and side view in orthographic projection. The technical terms which will be used in discussing perspective projection are given in the figure.

Notice that the PICTURE PLANE (PP) becomes a line in the top and side orthographic views. Projectors from the corners of the top view are drawn converging toward the STATION POINT (SP), but, from the points where the projectors or visual rays pierce the picture plane, parallel projectors are drawn down to the perspective view.

The station point for the side view is actually the same station point as that shown for the top view. It is, therefore, the SAME HORIZONTAL DISTANCE from the cube, but its elevation shows the height of the station point above the level of the cube. The picture plane in the side view is also the SAME DISTANCE from the cube as in the top view, and the ground line in this view, on which the picture plane rests, DEFINES the ground line of the picture plane in the perspective drawing.

From the side view, projectors are drawn converging to the station point, and at their piercing points on the picture plane, parallel horizontal projectors are drawn to the plane of the perspective drawing. The projectors from the top view are also made in the same manner, and vertical parallel projectors are drawn from the piercing point in the picture plane to the picture plane of the perspective drawing. The intersection point of a projector from a corner of the cube in the top view with the projector from the same corner in the side view locates the corner in the perspective drawing.

Notice that the center of vision in this drawing is located directly above the station point in the perspective drawing and on the same line with the station point for the elevation view (left side view in this case) of the cube. This line is the EYE LEVEL (EL) line, which is also the HORIZON line for the drawing.

The center of vision defines the point at which all lines perpendicular to the picture plane in the perspective drawing converge. It also coincides with the vanishing point in one-point perspective drawings. The fact that there is only ONE VANISHING POINT in this type of perspective drawing gives it its name. It is also called PARALLEL PERSPECTIVE, because the front face of the object is parallel to the picture plane.

In parallel perspective drawings, the center of vision is not necessarily centered on the object. It may fall to one side or the other as shown in figure 5-65. However, when the front face is parallel to the picture plane and the center of

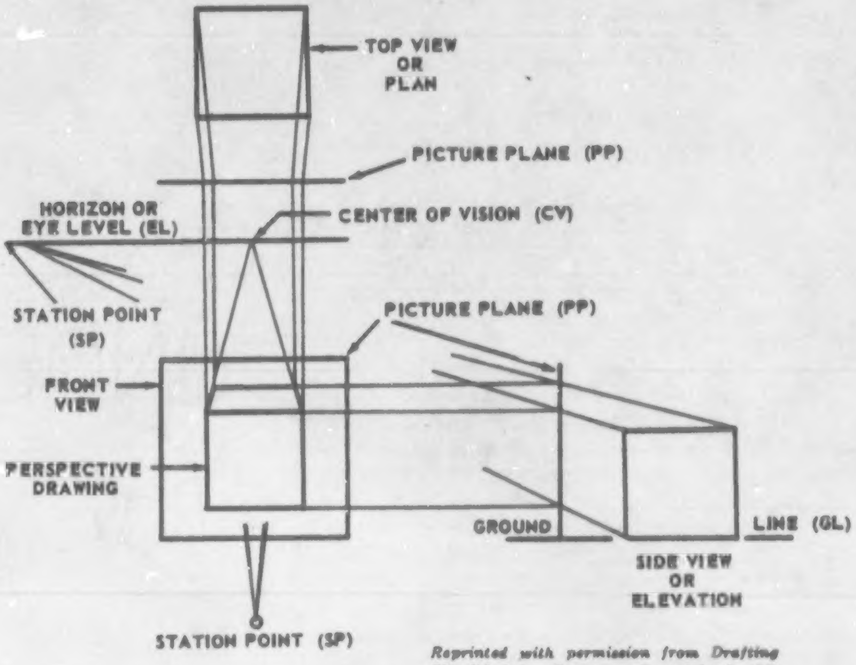
TOP VIEW
OR
PLAN
PICTURE PLANE (PP)
HORIZON OR
EYE LEVEL (EL)
CENTER OF VISION (CV)
STATION POINT
(SP)
PICTURE PLANE (PP)
FRONT
VIEW
PERSPECTIVE
DRAWING
GROUND
LINE (GL)
SIDE VIEW
OR
ELEVATION
STATION POINT (SP)

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Figure 5-64.—One-point perspective drawing obtained from orthographic views.

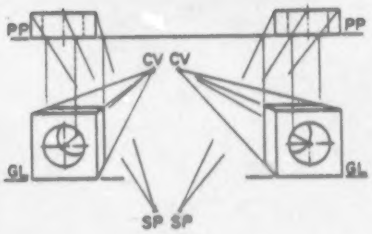
PP
PP
CV CV
GL
GL
SP SP

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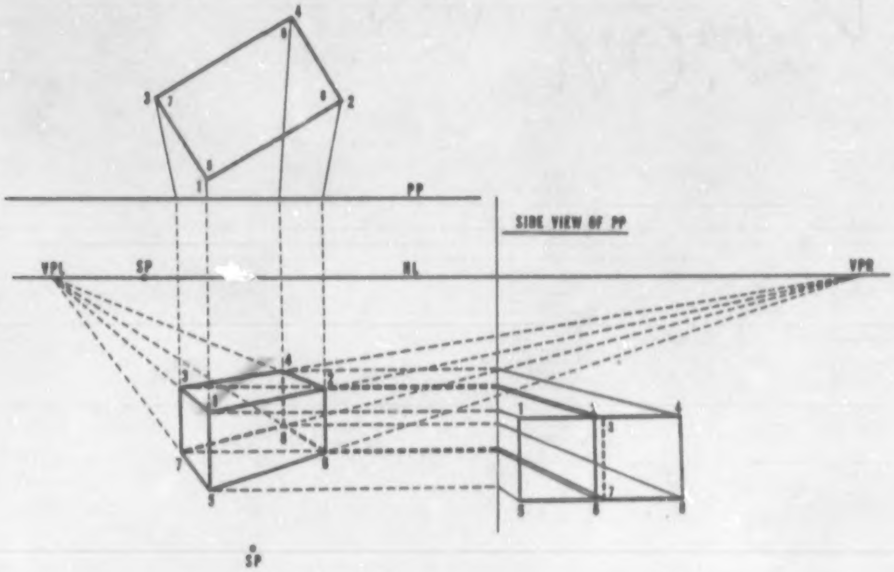
Figure 5-65.—Position of the station point at right or left of center in parallel perspective drawings.

vision is at one side of the drawing, there will necessarily be some distortion. Actually, the drawing approaches that of an oblique projection and will not appear as a true perspective drawing. Notice that in order to make such a drawing, the object must be considered as resting with its front face against the picture plane. If this were not so, converging projection lines from the corners of the front face would alter its appearance so that it would no longer appear to be parallel with the picture plane. In fact, as you will see, it would then become a two-point, rather than a one-point, perspective drawing.

TWO-POINT PERSPECTIVE

Two-point perspective is the most commonly used method for making perspective drawings. In two-point or angular perspective, the object is considered as sitting at an angle to the picture plane. In the perspective drawing of such an object, there are two sets of horizontal edges converging toward two different vanishing points on the eye level or horizon line. The parallel lines which slope to the right will vanish at a point in the distance called the RIGHT VANISHING POINT (VPR), and those that slope to the left at a point called the LEFT VANISHING POINT (VPL). The two-point or angular perspective of a cube is shown in figure 5-66. In this figure, the top orthographic view of the block was drawn



142.61
Figure 5-66.—Two-point or angular perspective.

first. The position of the picture plane was then determined.

When the corner of the object rests against the picture plane, the vertical line representing the corner in the perspective drawing will be full size. In one-view perspective, the front face is full size in the perspective drawing if it rests against the picture plane. In any perspective drawing, the comparative sizes will be reduced proportionately as the distance is increased between the picture plane and the object.

Once the picture plane was established, the station point for the top view in figure 5-66 was located approximately opposite the center of the block. The distance from the station point to the object should not be less than twice the width of the object.

When this rule is neglected, a distorted appearance may result in the perspective drawing. There is a cone of about 30° in which the human eye sees clearly. For this reason, the angle formed by the lines of sight from the sides of the object to the station point should not exceed 30°. In no case, even when the perspective drawing depicts a panoramic scene, should it exceed 45°.

Next, the picture plane for the side view was established. Then the side view was drawn. (Points may also be projected from the top view if necessary.) Remember that the picture plane in the side view or elevation is the same picture plane shown in the top view and, thus, it is the same horizontal distance from the object.

The station point for the side view was located next. This station point is the same point seen in the top view and, therefore, it is the same horizontal distance from the object. However, its angle to the object can vary. This variation of the station point in the side view determines the height of the eye level or horizontal line. Note that the station point for the side view always falls on the horizon line.

This horizon line is a very important one. If it is high, objects in the perspective view will appear as if they were viewed from a height. If it is low, objects will appear as if they were viewed from directly in front or below (see figure 5-69). Generally, it is best to select a station point approximately the position from which a real observer might view the object. This method is usually used when architectural drawings are made in two-point perspective. However, two-point perspective may be drawn from the plan view of the object alone, without the elevation. When this is done, the vanishing points are first projected on the picture plane and then located on the horizon line. In order to do this, a line parallel to one set of horizontal lines in the top view is drawn from the station point to the line of the picture plane. The point at which this line intersects the picture plane is then projected to the horizon line to locate a new point, either VPL or VPR (see fig. 5-67).

When this method is carefully used, it will produce as much accuracy as the method illustrated in figure 5-66. For example, in figure 5-68, the horizon line has been placed at the same level as the horizon line in figure 5-66 and the cube is the same size so that the two methods can be compared. In figure 5-66, the vanishing points were found after the drawing was completed, and it was not necessary that they be found at all. In figure 5-68, the vanishing points were found at the start, because they control the drawing.

In figure 5-68, lines are drawn converging toward the station point from the corners of the block in the top view. From the points where these lines pierce the picture plane, verticals are dropped to give the apparent width of the block in the perspective view. Since an elevation is not used, the various heights cannot be found directly. However, the bottom of the block may be located, as shown in figure 5-68, by drawing lines to the vanishing points from the point selected as the near corner.

Now if the perspective height of any one vertical line can be determined, the height of the other verticals can be found automatically. This is easy to do when one edge of the object rests against the picture plane. This edge will then appear in its true height in the perspective view. If you have the dimension for this height in the orthographic projection, you can transfer that dimension directly to the perspective view. Lines drawn to the vanishing points from this top corner will locate the top of the two sides, and lines drawn to the vanishing points from the far corners on these sides will complete the drawing of the block.

When the front edge of the object does not rest against the picture plane, it is necessary to use some other dimension. Since the end of the block is square, it is possible to find the perspective length of a horizontal line and use this dimension for the edge 1-5. This is done by drawing a line parallel to the picture plane from 1, measuring a length of this line equal to 1-3, and drawing a line converging on the station point to the picture plane from the end of this line.

This length can then be transferred to the front edge of the perspective view and the view completed as shown in figure 5-68. To check the accuracy of this method, compare figure 5

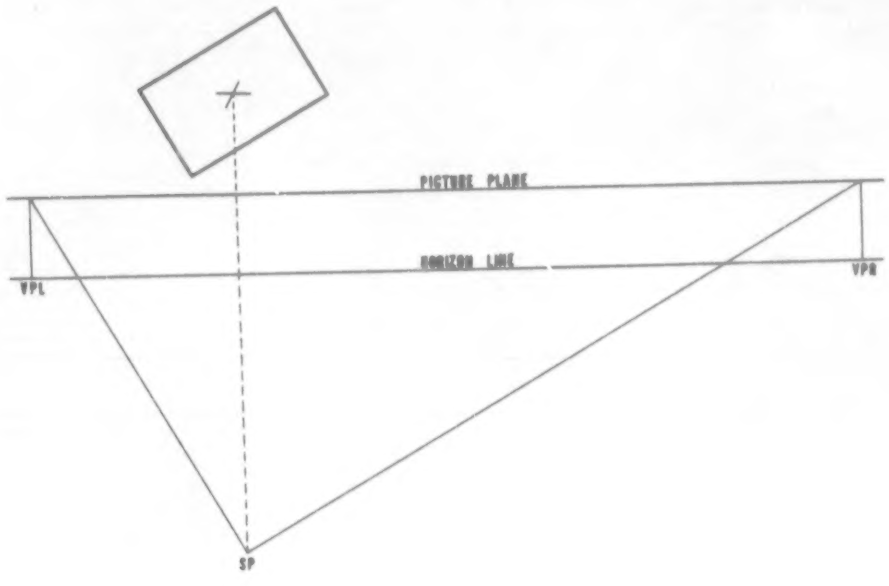


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Figure 5-67. — Locating vanishing points for two-point perspective drawn from the plan view.

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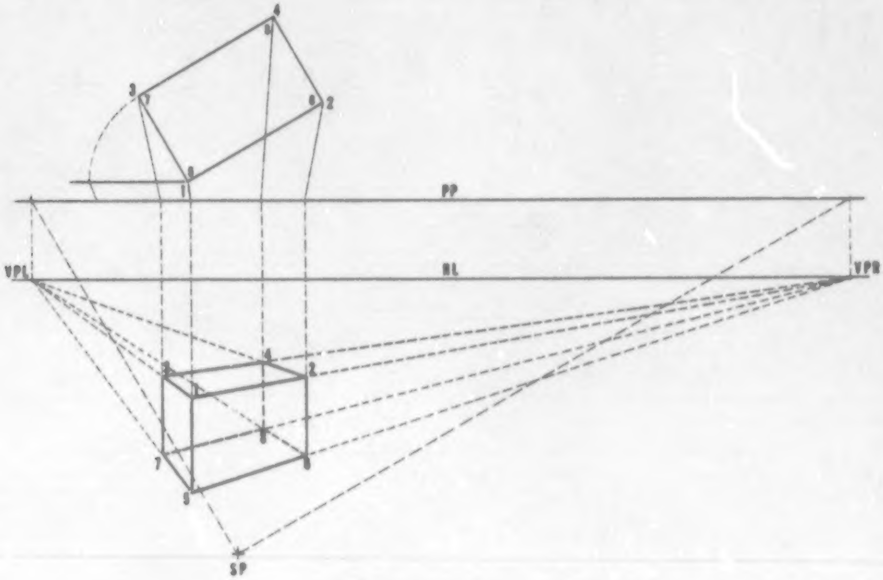

142.63
Figure 5-68.—Two-point perspective drawing made without using an elevation of the object.

with figure 5-66. You will find that, since the station point, horizon level, and bottom of the cube correspond, the two perspective views are similar. It is possible to make them correspond exactly.

In figure 5-68, the bottom of the front edge of the block has been placed automatically at a certain point. Actually, it could have been placed on the vertical projection from the cube at any desired point. Thus, the perspective view may be drawn below the eye level, or it may be drawn at eye level or above it; the latter two views are shown in figure 5-69.

However, if the object is placed too high above the eye level or too low below it, the effect will be one of distortion. A block drawn in these position will cease to look right, as shown in figure 5-70. When the station point is too close to the object, there will be a similar distortion. The angle indicated in the figure should never be less than 90° and preferably not less than 100°.

To overcome distortion such as that illustrated in figure 5-70, the station point may be moved further from the object, or the picture plane may be tilted so that a third vanishing point is needed for the third set of parallel lines in the drawing.

It is worth mentioning that, gridded media, in perspective or isometric grids, are available through commerical sources. These media will greatly facilitate your preparation of perspective or isometric drawings if properly used.

SKETCHING

The term "sketching" can be variously defined, but to a draftsman it means principally the making of a graphic representation with lines drawn free-hand, rather than with lines in the drawing of which the pencil or pen is guided by a straightedge, compass, french curve, or other mechanical device.

Chapter 3 of Blueprint Reading and Sketching, NavPers 10077-C, is entitled "Technical Sketching." That chapter contains about all you need to know on the subject.

REPRODUCTION PROCESSES

The original of the average technical drawing is carefully kept in a file, from which it is removed only to be revised or reproduced. The field supervisor or field worker gets a reproduction—that is, an exact copy reproduced on cheap but

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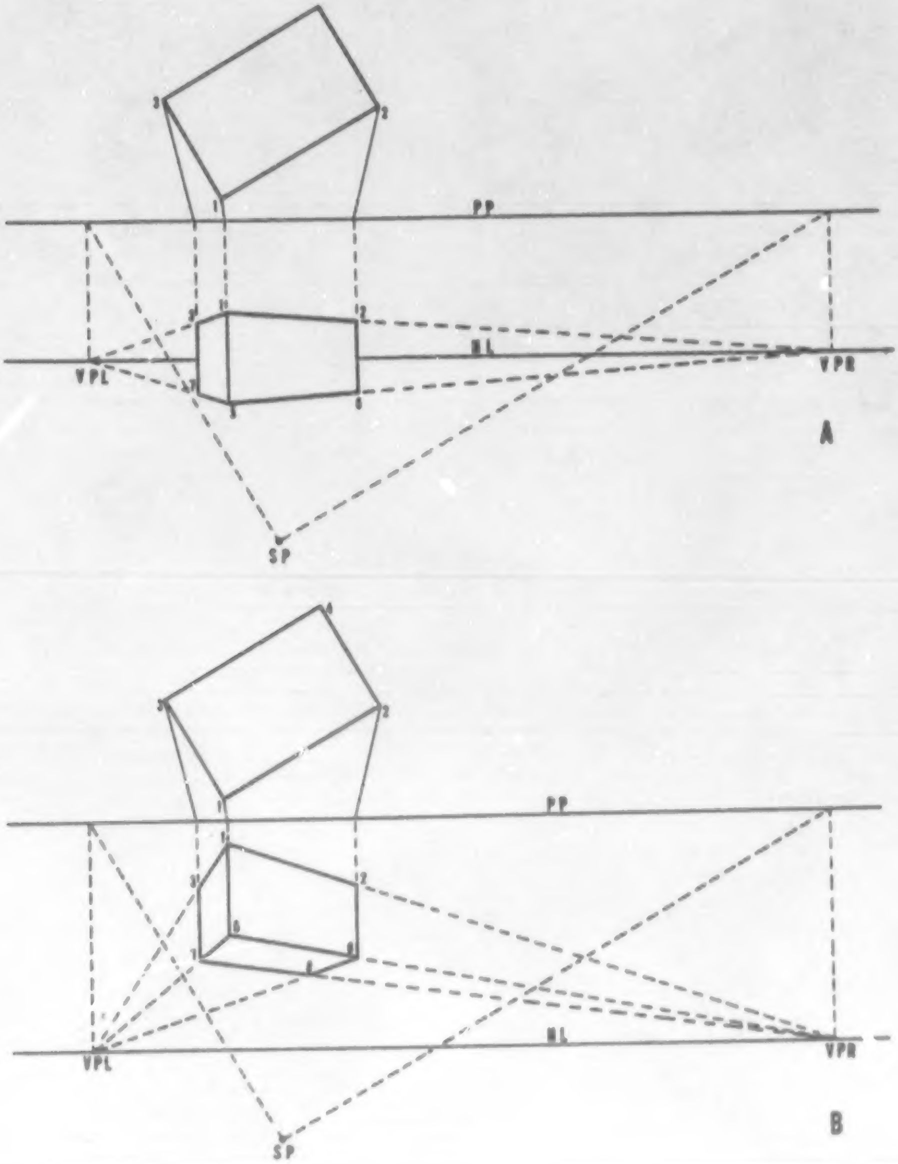
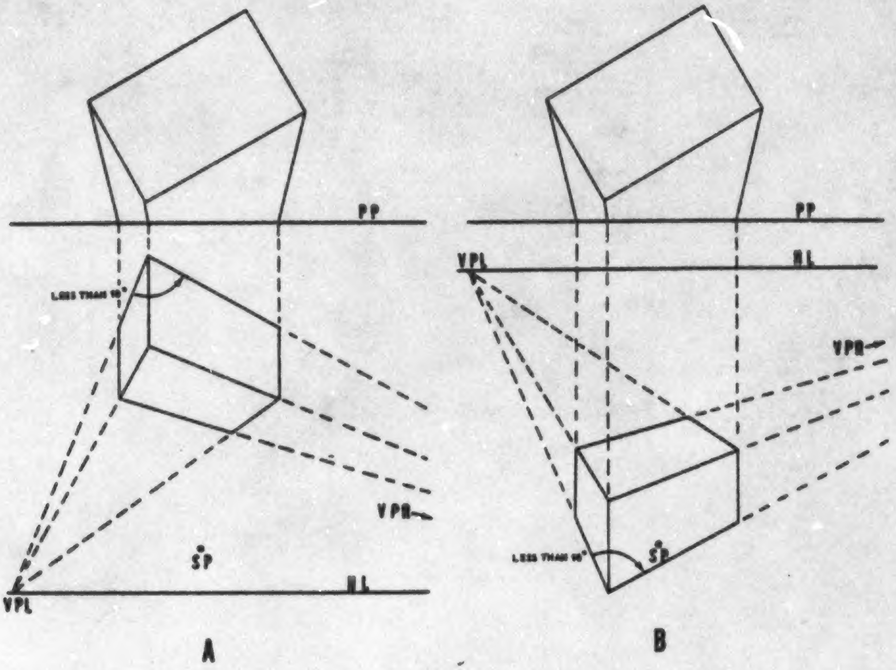


142.64
Figure 5-69.—(A) Object on eye level. (B) Object above eye level.

durable paper by the most economical reproduction process available.

Every one of the known reproduction processes, and the advantages and disadvantages of each, is described in Drawings and Specifications, NavDocks DM-6. This course can only briefly describe a few of the processes commonly used. Blueprinting is about the oldest but still the most commonly used. Next come vandyke or brownprinting, black-and-white printing, ammonia-vapor printing, photostat printing, and p[illegible]o-printing.



142.65

Figure 5-70.—(A) Object placed too high above eye level. (B) Object placed too low below eye level.

BLUEPRINTING

Blueprinting is done on paper which is chemically pretreated in a way which makes it sensitive to light. An original drawing in ink or semitransparent paper or cloth, or an inked tracing on the same, is placed with back against the sensitized face of the blueprint paper. When a strong light is turned on the paper, the areas which are not protected by ink lines on the drawing are chemically affected by the light.

These areas turn gray-blue in color. Later, when the print is "washed" as will be described, the areas turn dark blue. Areas which were protected by ink lines remain white. The result is a white-line reproduction of the drawing, as shown in figure 5-71.

After a print has been exposed to light, it is "washed" in clear water. The areas which were exposed to the light turn dark blue. The areas which were protected are washed clean of their chemical coating, so that they will remain white.

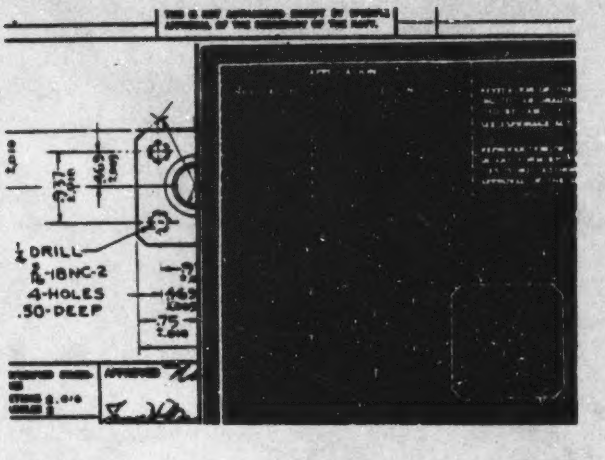
The print is then dipped in a chemical solution to "fix" (make permanent) the blue coating. The proportions of the fixing solution are 1 lb of potassium bichromate to 1 gal of water. The water should be at room temperature for mixing the solution. Place the potassium bichromate in the container first; add the water; and stir until all the chemical is dissolved.

After the print is fixed, it is washed in clear water a second time, to clear it of the fixing solution.

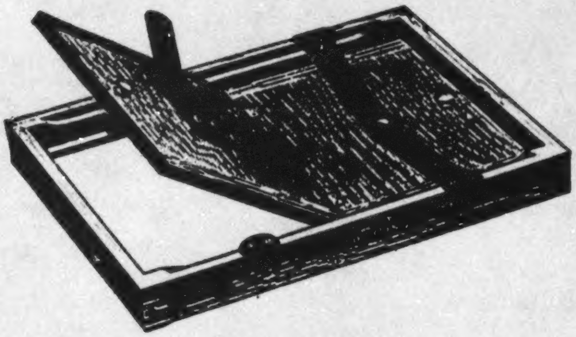
Sun Frames

The simplest type of blueprinting equipment is the sun frame shown in figure 5-72. The frame has a glass front and a removable back. The back is removed, the drawing to be reproduced is placed with face against the glass, a blueprint paper is fitted closely against the back of the drawing, and the back of the frame is replaced. The back is equipped with springs, as shown, to ensure close contact between blueprint paper and drawing.

To make the print, the glass front is exposed to sunlight for about 20 seconds to 4 minutes, depending on the brightness of the sunlight and



45.159
Figure 5-71.—Blueprinting produces a white-line reproduction of original drawing.



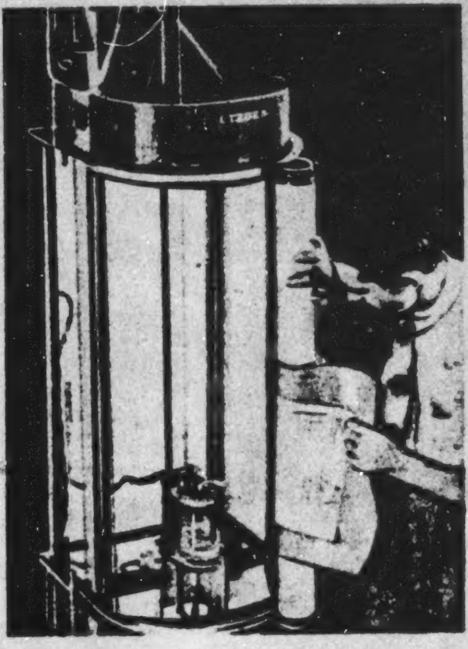
45.292
Figure 5-72.—Blueprinting sun frame.

the sensitivity of the paper. To avoid guesswork as to time of exposure, it is a good idea to allow an edge of the blueprint paper to protrude outside the frame, and to observe the color change on this edge. When it has turned gray-blue, exposure is sufficient.

The sun frame can be used only when the sun is out, and the size of the print it can make is limited to the relatively small size of the frame.

Vertical Blueprinting Machine

A vertical blueprinting machine (fig. 5-73) operates on electric light and will accommodate prints up to the largest standard size.



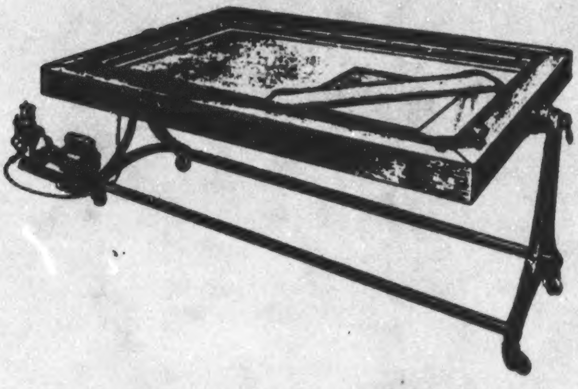
45.293
Figure 5-73.—Vertical blueprinting machi[illegible]

The machine contains a vertical glass cylinder, against which the face of the drawing is placed. A sheet of blueprint paper is placed against the back of the drawing, and the two are held in close contact by a roller-mounted curtain which is extended around the cylinder and clamped tightly in place. Time of exposure is from half a minute to several minutes, depending on the sensitivity of the print paper.

Vacuum Frame

A vacuum frame (fig. 5-74) is operated more or less like a sun frame, except that the source of light is a standing arc lamp rather than the sun. The frame is placed horizontally for inserting the drawing and print paper. It is then raised to vertical position for light exposure.

The distinguishing characteristic of a vacuum frame is the vacuum apparatus which ensures complete, tight contact between the back of the drawing and the sensitive side of the print paper. A rubber sheet is placed over the back of the paper and a vacuum pump exhausts all the air between the rubber sheet and the glass front. The vacuum thus created brings the drawin[illegible]nd the print paper into the tightest possible co[illegible]ct.



45.294
Figure 5-74.—Vacuum frame.

As a result of this arrangement, vacuum frame prints have exceptionally clear, sharp white lines.

Blueprinting Machine

A blueprinting machine is used for rapid reproduction of considerable numbers of prints. In a "noncontinuous" machine, cut sheets are fed through for exposure only, and then washed and fixed in separate apparatus. The automatic blueprint machine (fig. 5-75) is fed from a roll like a newspaper press, and combines exposure, washing, fixing, and drying in a single operation. Details and operating instructions must be obtained from the manufacturer's manual.

VANDYKES OR BROWNPRINTS

A vandyke, or brownprint, is distinguished from a blueprint by the fact that it is the lines that are blue, while the background is white. A negative print is made first, by the same process used for blueprinting. On the negative the lines are white and the background dark brown; hence the term "brownprint."

The negative is then used to make blueprints just as an original drawing is used—except that the resulting print has blue lines and a white background, instead of white lines and a blue background. An advantage of the system is the fact that the vandyke print, rather than the original drawing, takes the wear and tear of the reproduction process.

BLACK AND WHITE PRINTS

Black and white (BW) prints, like vandykes, have the lines colored and the background white. BW (often called by the trade-name "diazzo-moist" prints, however, are made directly from the drawing, without the necessity for an intermediate negative. Prints in black, red, brown, or blue lines may be made by the use of the appropriate BW paper in each case.

Prints may be made on a regular BW machine or on a blueprint machine equipped with BW attachments. A BW machine is a combination printer and developer. The drawing and BW paper are fed into a "printer" slot. When they emerge the BW paper is separated and fed into a "developer" slot. A print is dry and ready for use a few minutes after developing.

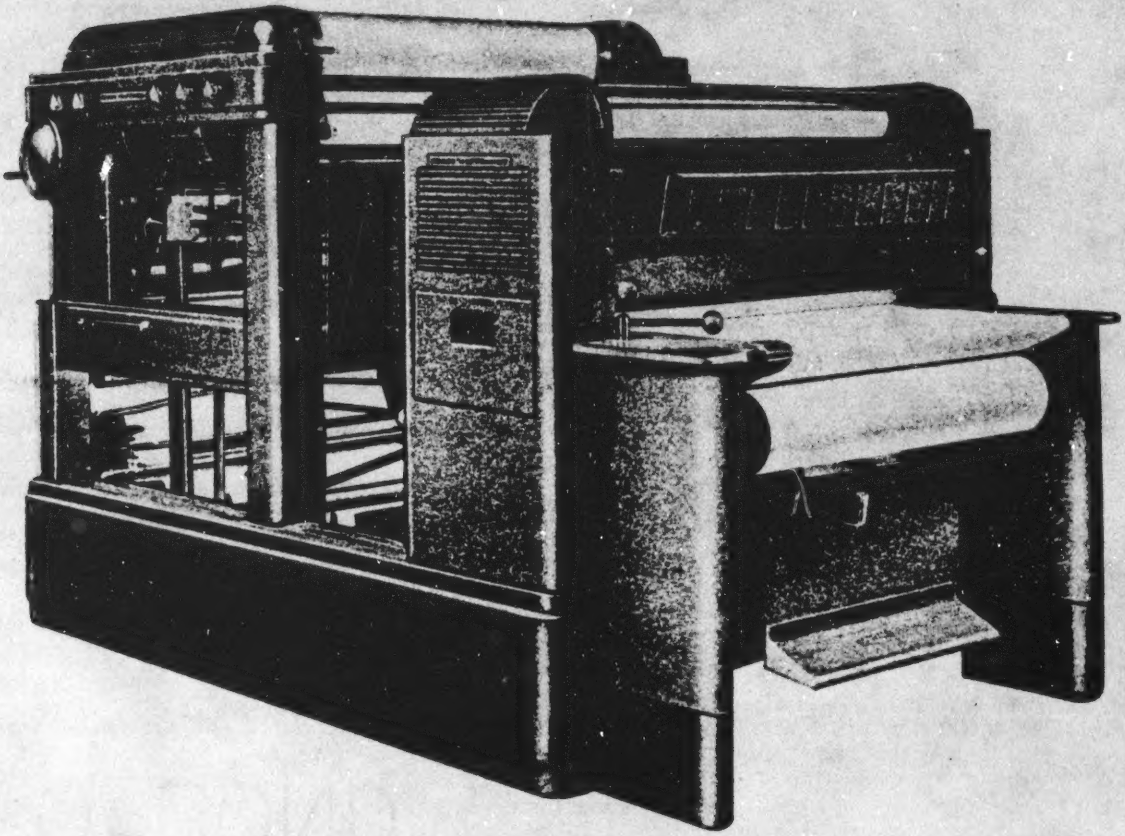
AMMONIA VAPOR PRINTS

The ammonia vapor process (better known by such trade names as "diazzo-dry" or "ozalid") also produces a print with colored lines and a white background, and also without the necessity for an intermediate negative.

Ammonia vapor process print paper is coated with a chemical which is sensitive to "actinic" light (ultra-violet lamps, mercury vapor lamps, carbon arc lights, and the sun are all sources of actinic light). An area of the paper which has been exposed to this light will turn white when it is exposed to ammonia vapor. An area which has not been so exposed will turn black, blue, or red, depending on the type of paper used.

The process is again basically similar to the blueprinting process. An ammonia vapor machine (fig. 5-76 shows an "ozalid streamliner") is equipped for first exposing a matched drawing and print paper to actinic light, and then exposing the print to ammonia vapor. On the ozalid streamliner the drawing and print paper are fed into a "printer" slot for light exposure. The machine is equipped with a separator device which separates the drawing (transparency) from the print paper. The drawing returns to the front (operator side), while the print paper continues in a different route into the "developer" slot for exposure to ammonia vapor. The machine may be set to receive the prints from the front or from the back.

At present, portable "ozalid" machines are generally used by the battalions. These portable printing machines have performed satisfactorily in taking care of all the printing needs of the battalion. Consult the manufacturer's handbook



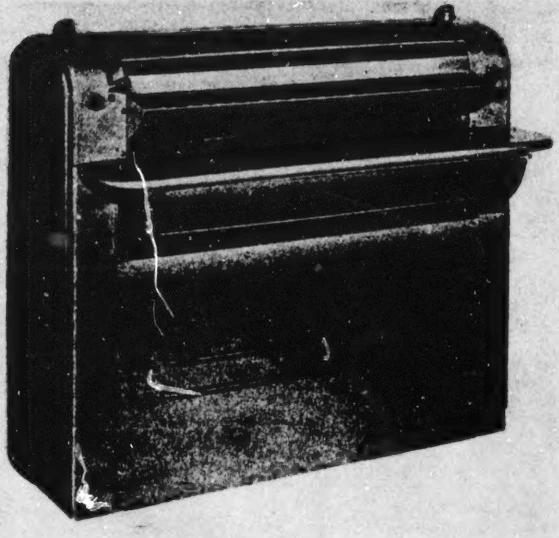
45.295X
Figure 5-75.—Automatic blueprinting machine.

for the proper operating and maintenance procedures for each particular machine. Your leading PO can fill you in on those parts that need frequent maintenance, repair, or replacement. Be sure to have enough spare parts in stock at all times—particularly before the battalion goes on a deployment.

PHOTOGRAPHIC CONTACT PRINTS

The reproduction processes which have been described are all forms of contact printing, so-called because a print or negative is placed in contact with the original for printing. Another form of contact printing is photographic contact printing. Here the original is set in close contact with a sheet of special photographic paper, either by a spring or by a vacuum arrangement similar to that of the vacuum frame. The original may be on either transparent or opaque paper or cloth. The paper is exposed to light, and the print is darkroom-developed like an ordinary photograph.

A photographic contact print paper has been developed on which an excellent positive print can be made directly from a transparent or opaque original on an ordinary blueprint, BW, or ammonia vapor machine, without the necessity for darkroom development.



45.296

Figure 5-76.—Ozalid streamliner.

PHOTOSTATS

The photostat method of reproduction is not a contact printing process like the others described, but a process similar to that of ordinary photography, except that the image is projected onto sensitized paper rather than onto photographic film, and the image is direct rather than reversed as on a photo negative. A photostat negative differs from the original and from the print in that its lines are white and background colored as shown in figure 5-77.

An advantage of the photostat process is the fact that negatives can be reproduced from originals, or prints from negatives, in reduced or enlarged sizes. However, the best photostats are not as clear as good contact prints, and reducing or enlarging a print from a negative produces perceptible distortion. There is also some distortion when a negative is reduced or enlarged from an original, but it is very slight.

PHOTOPRINTS

A photoprint is simply a blueprint which is made from a photostat negative rather than from an original drawing.

OVERHEAD OR OPAQUE PROJECTOR

An overhead or opaque projector is not, strictly speaking, a reproducer, but only a machine for projecting an image of a graphic representation onto a movie screen. It is similar to the familiar slide projector, except that it projects an image which is reflected from the surface of the drawing, instead of projecting an image by shining a light through a transparent film. Consequently, it can project drawings made on opaque material. The Salzman projector is shown in figure 5-78. It is very helpful in reproducing area maps from a small scale to a larger scale in preparing site plan drawings. As you can see the overhead projector slides up or down making it possible to adjust the projected image to exactly the desired scale. Some projectors have reversible lenses, which are used for enlarging or reducing drawings.

TRACING TABLE

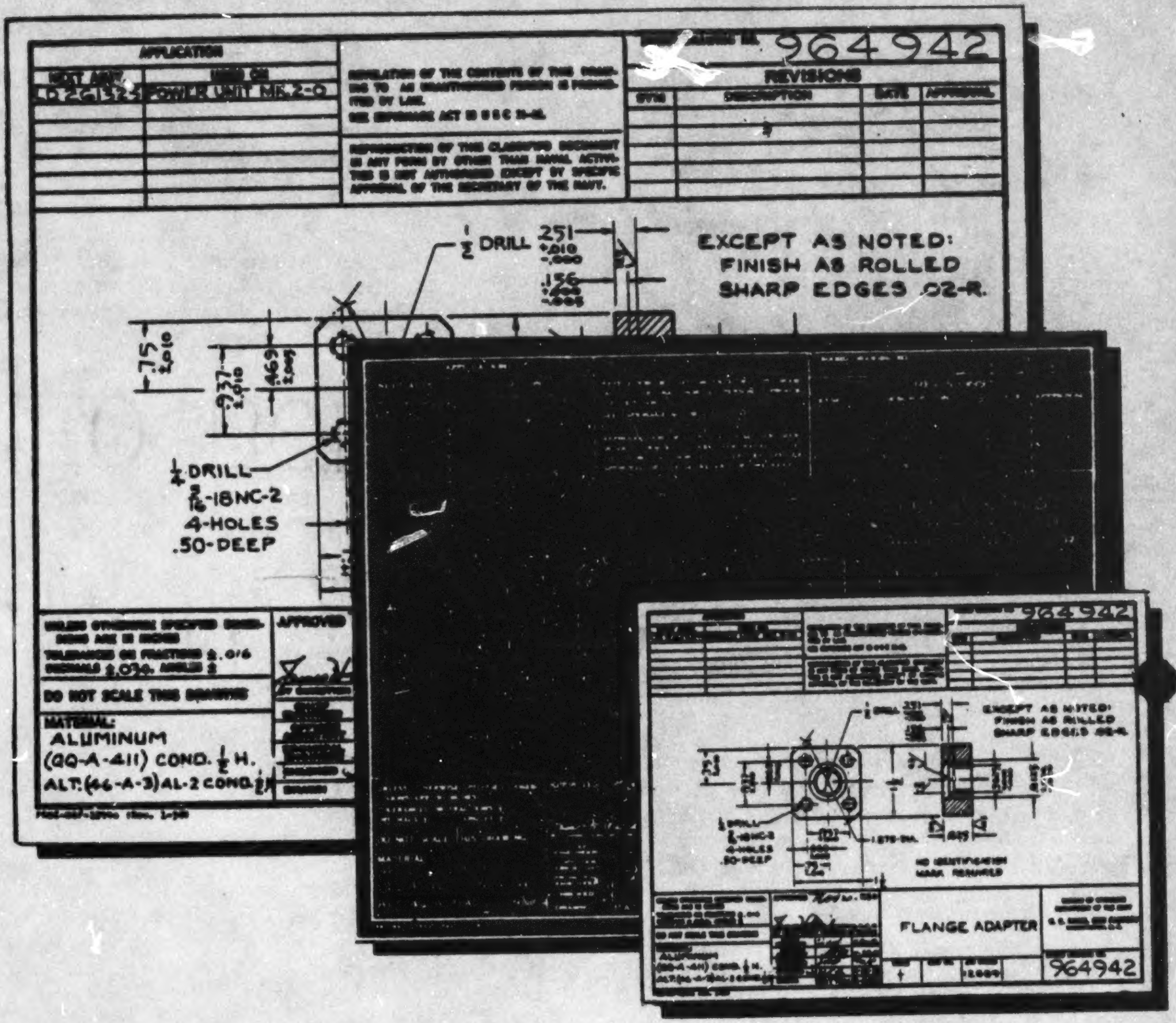
The tracing table is nothing but an ordinary drafting table with a see-through glass top and a powerful light boxed-in under it. Generally, if you can get the glass top, the table can be constructed easily in your battalion's carpentry shop. Two ordinary fluorescent lamps, rigged under the table, will give enough lighting, as long as they are boxed-in properly.

The tracing table, as the name suggests, is used primarily for tracing drawings. Depending on how the table is constructed, it sometimes will overheat, so be sure to switch off the light when you leave your work—even just for a coffee break.

FILING DRAWINGS

For our purposes here, the term "filing" means (1) the protected stowage of a large number of items with the greatest possible economy of space, and in a manner which makes it possible for any single item to be readily located; and (2) the maintenance of a file record in which all items on file are recorded, and in which the record of any single item (including its location in the file) may also be readily located.

Every important technical drawing is identifiable by a drawing number. The number is assigned by the agency which made the drawing, and the agency ensures that there are no duplications of


APPLICATION
POWER UNIT MK.2-0
964942
REVISIONS
DESCRIPTION
DATE
APPROVAL
EXCEPT AS NOTED:
FINISH AS ROLLED
SHARP EDGES .02-R.
$\frac{1}{2}$ DRILL
.251
.156
.75
.937
.469
$\frac{1}{4}$ DRILL
$\frac{5}{16}$-18NC-2
4-HOLES
.50-DEEP
DO NOT SCALE THIS DRAWING
APPROVED
MATERIAL:
ALUMINUM
(QQ-A-411) COND. $\frac{1}{2}$ H.
ALT.(46-A-3) AL-2 COND.
FLANGE ADAPTER
964942

45.159

Figure 5-77.—Photostat original, negative (reduced), and print (further reduced).

numbers. The first major file breakdown for drawings, then, is a breakdown into separate files for the different agencies which have supplied the drawings. Within each agency file, the most convenient way to file drawings and prints is by numerical sequence of drawing numbers.

FILING ORIGINALS

The following sections discuss the matter of filing under quite ideal conditions—especially with regard to equipment. Therefore, the equipment mentioned here may or may not be available.

Original drawings, tracings, and negatives are filed flat—never folded. For large items there are shallow-drawer file cabinets of the type shown in figure 5-79. There is usually a deep drawer at the bottom in which very large drawings, tracings, or negatives, rolled and placed in cylindrical cartons called "map cartons," may be stowed.

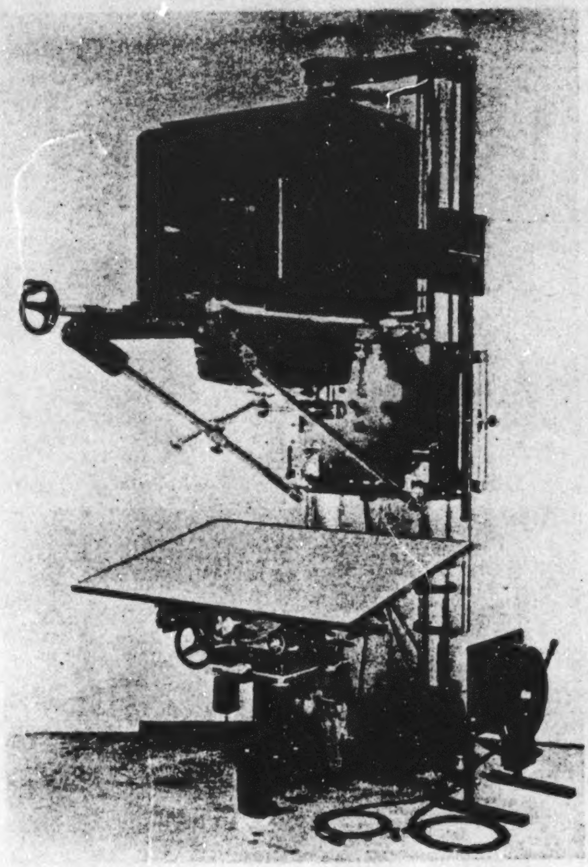


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Figure 5-78.—Saltzman overhead projector.

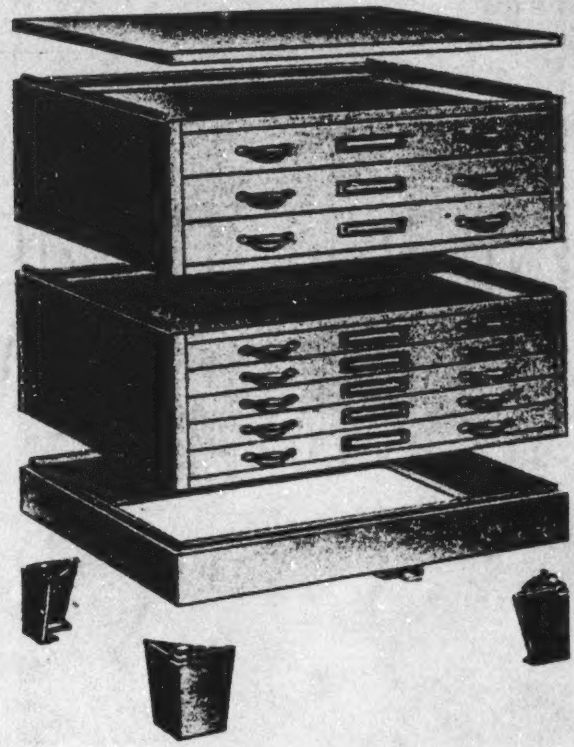

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Figure 5-79.—Shallow-drawer type cabinet for filing large original drawings, tracings and negatives.

Smaller items (up to size B, 11 in. x 17 in.) are stowed on edge in the standard deep-drawer type of cabinet, as shown in figure 5-80. Each drawer is divided into compartments by stationary partitions, and in each compartment there is a "compressor spring" to keep the drawings on edge and in a compressed stack.

FILING PRINTS

Prints, regardless of size, are stowed on edge in the standard deep-drawer type of cabinet. Prints larger than size B must be folded. A print is folded in accordion-pleat type folds, in such a manner as to ensure that the drawing number is outside after the print has been folded. Final folded size should be 8-1/2 in. x 11 in. You should make yourself a plastic or plywood 8-3/8 in. x 10-7/8 in. "folding guide," or procure a ready-made one of these. The steps in folding a large print are as follows:

1. Fold the print into 10-7/8 in. lengthwise accordion-pleat folds first. Lay the print face-down, and start by turning up the edge containing the drawing number, using the folding guide as shown in figure 5-81. Use a small block of wood, like the one shown in the figure, to compress the crease.

2. Turn the print over and make the next lengthwise fold as shown in figure 5-82. Continue turning over and folding until the width of the drawing is used up.

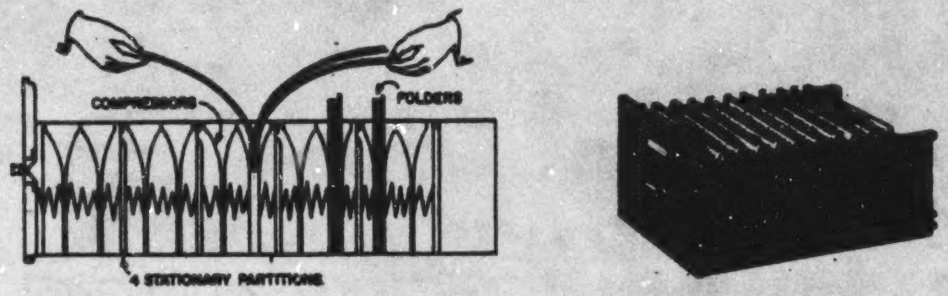

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Figure 5-80.—Drawer of cabinet used for filing small original drawings, tracings, and negatives.

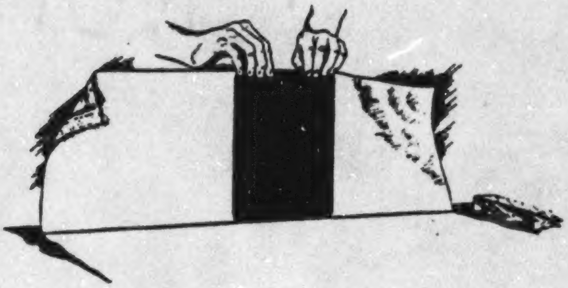

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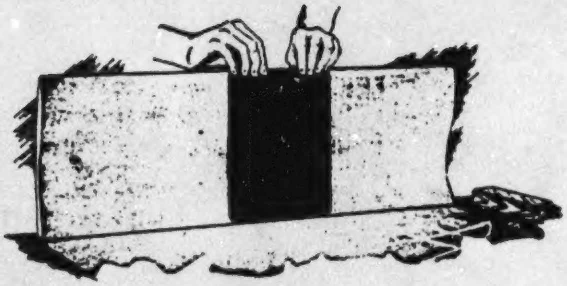
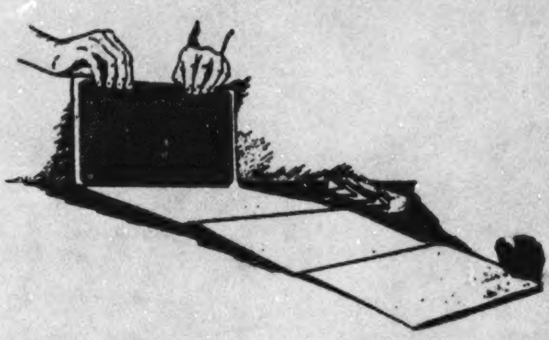
Figure 5-81.—Making first lengthwise fold in a large print.



45.301
Figure 5-82.—Making second lengthwise fold in a large print.



45.302
Figure 5-83.—Making first crosswise fold in a large print.

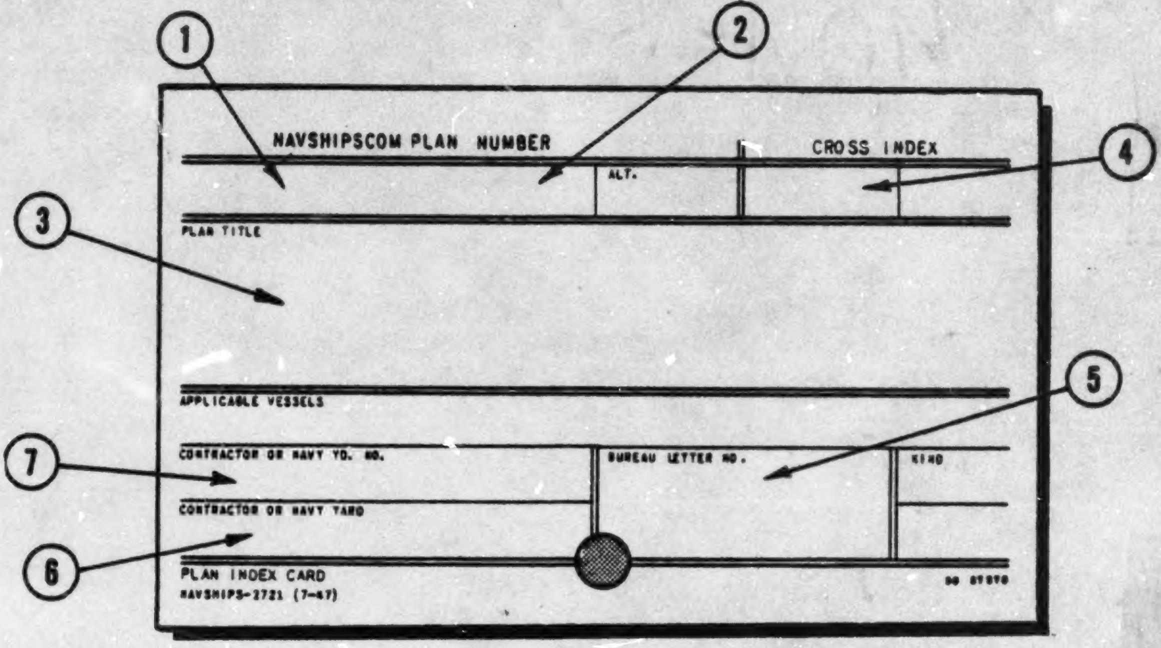
3. Place the lengthwise-folded drawing so that the side on which the drawing number appears is down. Begin at the end which contains the drawing number, and make the first 8-1/2 in. crosswise accordion-pleat fold, using the folding guide as shown in figure 5-83.

4. Turn the print over and make the next fold. Continue until the length of the drawing is used up.

Folded prints are stowed in the same type of deep-drawer cabinet used for stowing small originals. Prints of drawings for active projects are generally placed on STICK FILES for easy reference.

FILING DATA

Data relating to drawings, such as correspondence, should be filed in accordance with SecNavInst. 5210.11A (described later), or if a limited



45.303
Figure 5-84.—NavShipSysCom drawing file index card.

number of drawings are affected, they can be filed by drawing numbers in a separate drawer or cabinet. If a separate folder for each project is maintained, such data must be filed in that folder.

FILE RECORD

A record of each drawing should be kept on an index card in a suitable file drawer. The different agencies which produce drawings prepare their own types of index cards. The type of card issued by the Naval Ship Systems Command (NAVSHIPSYSCOM), for example, is shown in figure 5-84. A brief description of the information which would be entered in each of the numbered spaces shown in this card is as follows:

1. The "numerical subject identification code" and/or the "name-title subject identification code." These classification codes are prescribed in the Department of the Navy Standard Subject Identification Codes Manual, SecNav Instruction 5210.11A. A copy of this instruction is available in the personnel office and in the technical library. The classification systems in this manual are designed to meet the needs of the entire Department of the Navy for a single, standard subject scheme to be used in numbering, arranging and filing, and referencing various types of Navy and Marine Corps documents by subject.

The Standard Subject Identification Codes System is generally employed by large shore activities, such as Public Works Departments, CB Centers, Brigade Headquarters, and so on. For smaller mobile units, such as the Battalion, the EA in charge of the drafting room or the Operations Chief may devise his own indexing system for the filed drawings that suits the volume of records handled by his unit.

2. The drawing number. As you can see, NavShipSysCom calls this the "Plan Number." NAVFAC calls it the "NFEC Drawing Number."

3. The title of the drawing, taken from the title block.

4. Cross-index references to any correspondence or data which may be on file relating to the drawing.

5. Number of the Bureau letter, if any, which was forwarded with the drawing.

6. & 7. The number and name of the A & E firm, contractor, naval shipyard, or other agency which actually made the drawings.

Again, if a separate folder or drawer file is maintained for each project, a notation must be placed in the folder as to where to find the drawings related to that project. The project number will appear in the cross-index block (4) of the index card.